US Army Corps of Engineers

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PROCEEDINGS OF THE 52ND MEETING OF THE COASTAL ENGINEERING RESEARCH BOARD

17-19 October 1989

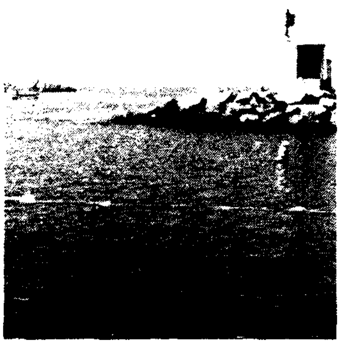
REDONDO BEACH, CALIFORNIA

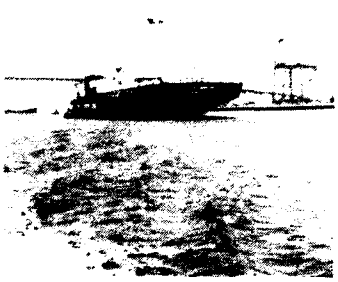
Hosted by

US Army Engineer Division, South Pacific

and

US Army Engineer District, Los Angeles





June 1990

Final Report

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These proceedings provide summaries of the papers presented at the semiannual meeting of the Coastal Engineering Research Board (CERB). Also included are discussions of CERB business, recommendations for research and development by CERB members, and public comment.

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PREFACE

The Proceedings of the 52nd Meeting of the Coastal Engineering Research Board (CERB) were prepared for the Office, Chief of Engineers, by the Coastal Engineering Research Center (CERC), of the US Army Engineer Waterways Experiment Station (WES). These proceedings provide a record of the papers presented, the questions and comments in response to them, and the interaction among program participants and the CERB.

The meeting was hosted by the US Army Engineer Division, South Pacific, under the direction of BG(P) John F. Sobke, Commander, and the US Army Engineer District, Los Angeles (SPL), under the direction of COL Charles S. Thomas, Commander.

Acknowledgments are extended to the following: Mr. Arthur T. Shak, SPL, who assisted with the coordination of the meeting; Mr. Ted Baldau, SPL, who coordinated the field trip; Mses. Jennie Ayala, Pam Castens, and Margie Tizon, SPL, who assisted with various administrative details for the meeting. Thanks are extended to guest participants Mr. William H. Ivers, State of California Department of Boating and Waterways; Mr. Robert W. Caughlan, Surfrider Foundation; Honorable Larry M. Bagley, Mayor, City of Oceanside; Mr. Dan T. Kochi, Deputy Director for State Harbors, State of Hawaii; Messrs. Dwayne G. Lee and John F. Warwar, Port of Los Angeles; and Mrs. Geraldine Knatz, Port of Long Beach. Thanks are extended to Mrs. Sharon L. Hanks for coordinating and assisting in setting up the meeting and assembling information for this publication; Dr. Fred E. Camfield for preparing the draft proceedings from the transcript; the Information Technology Laboratory for editing these proceedings; Mrs. Karen R. Wood for typing, all of whom are at WES. Thanks are extended also to Ms. Dale N. Milford, Certi-Comp Court Reporters, Inc., for taking verbatim dictation of the meeting.

The proceedings were reviewed and edited for technical accuracy by Dr. James R. Houston, Chief, CERC, and Mr. Charles C. Calhoun, Jr., Assistant Chief, CERC. COL Larry B. Fulton, Executive Secretary of the Board and Commander and Director, WES, provided additional review.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

Patrick J. Kelly

PATRICK J. KELLY
Major General, US Army
President, Coastal Engineering
Research Board

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INTRODUCTION

The 52nd Meeting of the Coastal Engineering Research Board (CERB) was held at the Sheraton at Redondo Beach, California, on 17-19 October 1989. It was hosted by the US Army Engineer Division, South Pacific (SPD), under the direction of BG(P) John F. Sobke, Commander, and the US Army Engineer District, Los Angeles (SPL), under the direction of COL Charles S. Thomas, Commander.

The Beach Erosion Board (BEB), forerunner of the CERB, was formed by the US Army Corps of Engineers in 1930 to study beach erosion problems. In 1963, Public Law 88-172 dissolved the BEB by establishing the CERB as an advisory board to the Corps and designating a new organization, the Coastal Engineering Research Center (CERC), as the research arm of the Corps. The CERB functions to review programs relating to coastal engineering research and development and to recommend areas for particular emphasis or suggest new topics for study. The Board's four military and three civilian members officially meet twice a year at a particular coastal Corps District or Division to do the following:

a. Disseminate information of general interest to Corps coastal Districts and Divisions.

b. Obtain reports on coastal engineering projects in the host (local) District or Division; receive requests for research needs.

c. Provide an opportunity for state and private institutions and organizations to report on local coastal research needs, coastal studies, and new coastal engineering techniques.

d. Provide a general forum for public inquiry.

e. Provide recommendations for coastal engineering research and development.

Presentations during the 52nd CERB meeting dealt with Pacific coastal and navigation challenges. Documented in these proceedings are summaries of presentations made at the meeting, discussions that followed these presentations, and recommendations by the Board. A verbatim transcript is on file at CERC, US Army Engineer Waterways Experiment Station (WES).

THE COASTAL ENGINEERING RESEARCH BOARD
OCTOBER 1989

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52ND COASTAL ENGINEERING RESEARCH BOARD MEETING

Redondo Beach, California
17-19 October 1989

ATTENDEES

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Professor Fredric Raichlen
Professor Robert O. Reid

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Mr. Frank H. Posey, CESAS-EN-HC

SOUTH PACIFIC DIVISION
Mr. Hugh D. Converse, CESPD-PD
Mr. George W. Domurat, CESPD-ED-W

SOUTH PACIFIC DIVISION (CONTINUED)
Mr. Jaime R. Merino, CESPD-ED-W
Mr. Douglas M. Pirie, CESPD-CO-O
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Mr. Chris J. Andrassy, CESPL-ED-DC
Ms. Jennie Ayala, CESPL-ED-DC
Mr. Ted W. Baldau, CESPL-ED-DC
Ms. Pam G. Castens, CESPL-PD-CS
Mr. Inocencio P. Di Ramos, CESPL-ED-DC
Mr. Carl F. Enson, CESPL-CO
Mr. John Ferguson, Jr., CESPL-ED-GG
Mr. Robert L. Hall, CESPL-ED-D
Dr. A. L. (Latif) Kadib, CESPL-PD-CS
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Mr. D. Chuck Mesa, CESPL-ED-DC
Mr. Thomas E. Mitchell, CESPL-CO-O
Mr. Bruce H. Neubauer, CESPL-ED-DC
Mr. Tad Nizinski, CESPL-ED-DC
Mr. Bob Nurai, CESPL-ED-SM
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Mr. Tony Price, CESPL-ED-GG
Mr. Arthur T. Shak, CESPL-ED-DC
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CPT Phyllis Spivey, CESPL-CO
Ms. Margie A. Tizon, CESPL-ED-DC
COL Galen H. Yanagihara, CESPN
Mr. William J. Brick, CESPN-PE-W

SOUTHWESTERN DIVISION
Mr. Thomas R. Kincheloe, CESPW-PL-P

WATERWAYS EXPERIMENT STATION
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Dr. James R. Houston, CEWES-CV-Z
Mr. H. Lee Butler, CEWES-CR
Mr. Charles C. Calhoun, Jr., CEWES-CV-A
Dr. Fred E. Camfield, CEWES-CW
Mr. C. E. Chatham, Jr., CEWES-CW
Mr. D. D. Davidson, CEWES-CW-R
Ms. Sharon L. Hanks, CEWES-CV-AC
Mr. J. Michael Hemsley, CEWES-CP-C
Mr. Gary L. Howell, CEWES-CD-P
Dr. Nicholas C. Kraus, CEWES-CR
Ms. Linda S. Lillycrop, CEWES-CR-O
CPT(P) James N. Marino, CEWES-CV
Mr. William H. McAnally, CEWES-HE
Mr. David D. McGehee, CEWES-CD-P

52ND COASTAL ENGINEERING RESEARCH BOARD MEETING

ATTENDEES (Concluded)

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Mr. Jeffrey A. Melby, CEWES-CD-P
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Mr. William L. Preslan, CEWES-CD-P
Dr. Donald K. Stauble, CEWES-CD-SG
Dr. C. Linwood Vincent, CEWES-CP-C

US MILITARY ACADEMY, WEST POINT

COL William J. Reynolds

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Honorable Larry M. Bagley, Mayor of Oceanside, California
Mr. Timothy J. Casey, City of Redondo Beach, California
Mr. Robert W. Caughlan, Surfrider Foundation, Menlo Park, California
Mr. William H. Ivers, Department of Boating and Waterways, Sacramento, California
Dr. Geraldine Knatz, Port of Long Beach, California
Mr. Dan T. Kochi, Department of Transportation, State of Hawaii
Mr. Dwayne G. Lee, Port of Los Angeles, California
Mr. John F. Warwar, Port of Los Angeles, California

GUESTS

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Mr. George A. Armstrong, Department of Boating and Waterways, Sacramento, California
Mr. Ron Flick, Department of Boating and Waterways, LaJolla, California
Mr. Angel Fuertes, Port of Long Beach, California
Mr. John Hale, John Hale Coastal Engineering, Inc., Baldwin Park, California
Mr. Vern Hall, Port of Los Angeles, California
Dr. Young C. Kim, California State University, Los Angeles, California
Mr. Wayne D. Lasch, Greenhorne and O'Mara, Inc., Greenbelt, Maryland
Mr. Marvin L. Luther, Harbor Commission, City of Redondo Beach, California
Ms. Judith R. Meister, City of Santa Monica, California

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Mr. Robert A. Nathan, Moffat and Nichol, Engineers, Long Beach, California
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Mr. Ronald M. Noble, Noble Consultants, Inc., Irvine, California
Ms. Michele Okihiro, Scripps Institution of Oceanography, LaJolla, California
Mr. Richard W. Parsons, Ventura Port District, Ventura, California
Mr. Thomas P. Pratte, Surfrider Foundation, Huntington Beach, California
Ms. Sheila Schoettger, City of Redondo Beach, California
Dr. Richard J. Seymour, Scripps Institution of Oceanography, LaJolla, California
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Mr. Greg Woodell, County of Los Angeles, California

COURT REPORTER

Ms. Dale N. Milford, Certi-Comp Court Reporters, Inc., Jackson, Mississippi

52ND MEETING OF THE COASTAL ENGINEERING RESEARCH BOARD
17-19 October 1989
Sheraton at Redondo Beach
Redondo Beach, California

AGENDA

THEME: Pacific Coastal and Navigation Challenges

MONDAY, 16 October

1830 -	Registration and Social Function	

TUESDAY, 17 October

0730 - 0800	Registration	
0800 - 0810	Opening Remarks and Introduction of New Board Members	MG Robert M. Bunker, SAD
0810 - 0820	Welcome to South Pacific Division and Los Angeles District	COL Galen H. Yanagihara, SPN LTC Glen F. Weien, SPL
0820 - 0850	Review of CERB Business	COL Larry B. Fulton, WES
0850 - 0900	Review of Coastal Engineering R&D Program	Dr. James R. Houston, CERC/WES
0900 - 0955	Hugo Update Introduction CERC Activities Shoreline Profiles and Damage Assessment	 MG Robert M. Bunker, SAD Dr. James R. Houston Dr. Donald K. Stauble, CERC/WES
0955 - 1005	BREAK	
1005 - 1035	Pacific Ocean Division Research Needs	Mr. Stanley J. Boc, Jr., POD
1035 - 1115	Review of State of California Activities	Mr. William H. Ivers, Director, State Department of Boating and Waterways
1115 - 1145	South Pacific Division Coastal Engineering Research Needs	Mr. George W. Domurat, SPD
1145 - 1200	Field Trip Overview	Mr. Arthur T. Shak, SPL
1200 - 1300	LUNCH	

1300 -	Meet at: Catalina Express Dock King Harbor 161 North Harbor Drive Redondo Beach, California	
1330 - 1730	Field Trip: Redondo Beach (King Harbor) El Segundo Beach Nourishment Marina Del-Rey Santa Monica Breakwater and Pier Rancho Palos Verdes Port of Los Angeles and Long Beach Queen Mary	
1730 - 1930	Free time (transportation provided to hotel for persons not attending social and dinner)	
1930 -	Social Hour and Dinner (*Queen Mary*)	

WEDNESDAY, 18 October

0815 - 0830	Opening Remarks	BG Robert C. Lee, SWD
0830 - 1030	Unique Coastal Challenges	
0830-0900	If Everybody Had an Ocean...	Mr. Robert W. Caughlan, Surfrider Foundation
0900-0950	Crescent City Prototype Dolosse Study, Field Measurements Design Methodology	Mr. Gary L. Howell, CERC/WES Mr. Jeffrey A. Melby, CERC/WES
0950-1010	Oceanside Sand Bypass System	Honorable Larry M. Bagley, Mayor, City of Oceanside
1010-1030	Coast of California Study	Dr. A. L. Kadib, SPL Honorable Larry M. Bagley, Mayor, City of Oceanside
1030 - 1045	BREAK	
1045 - 1235	Pacific Harbors	
1045-1115	King Harbor (Redondo Beach)	Mr. Timothy J. Casey, City Manager, City of Redondo Beach
1115-1135	Model Studies of Redondo Beach King Harbor, California	Mr. C. E. Chatham, Jr., CERC/WES

AGENDA (Concluded)

1135-1205	Hawaii's Statewide System of Commercial Harbors	Mr. Dan T. Kochi, Deputy Director for State Harbors, State of Hawaii
1205-1235	Barbers Point Deep-Draft Harbor	LTC Donald T. Wynn, POH
1235 - 1335	LUNCH	
1335 - 1645	Los Angeles/Long Beach (LA/LB) Harbors	
1335-1435	LA/LB 2020 Plan	Mr. Dwayne G. Lee, Deputy Executive Director, Development, Port of Los Angeles Mr. John F. Warwar, 2020 Program Director, Port of Los Angeles Dr. Geraldine Knatz, Director of Port Planning, Port of Long Beach Mr. Alan E. Alcorn, SPL
1435-1505	LA/LB Harbors Model Enhancement Program	Mr. C. E. Chatham, Jr., CERC/WES
1505-1525	BREAK	
1525-1605	Field Measurements in Support of the LA/LB Model Harbors Enhancement Upgrade	Mr. David D. McGehee, CERC/WES
1605-1645	LA/LB Harbors Model Enhancement Program: Three-Dimensional Hydro-Environmental Model	Mr. H. Lee Butler, CERC/WES
1645	ADJOURN	

THURSDAY, 19 October

0800 - 0805	Opening Remarks	COL Daniel M. Wilson
0805 - 0835	Update on Dredging Research Program, Problem Area No. 1	Dr. Nicholas C. Kraus, CERC/WES
0835 - 0905	Public Comment	
0905 - 1005	Board Recommendations	CERB
1005 - 1020	Closing Business and Remarks	COL Daniel M. Wilson
1020	**ADJOURN**	

OPENING REMARKS
AND
WELCOME TO SOUTH PACIFIC DIVISION
AND LOS ANGELES DISTRICT

MG Robert M. Bunker opened the 52nd Meeting of the Coastal Engineering Research Board, acting for BG(P) Patrick J. Kelly, President of the Board who was unable to join the meeting. He welcomed back continuing members of the Board and welcomed new members Dr. Robert A. "Tony" Dalrymple, Professor of Civil Engineering and Director of the Center of Applied Coastal Research at the University of Delaware; Dr. Fredric Raichlen, Professor of Civil Engineering at the California Institute of Technology; and COL Daniel M. Wilson, Commander, New England Division. He then turned the floor over to COL Galen Yanagihara, Commander, San Francisco District.

COL Yanagihara welcomed attendees to the SPD on behalf of BG(P) John F. Sobke, who was unable to be at the meeting. He said SPD was honored to be the host for the Board's 52nd meeting. California's coastal area includes some of the Nation's most environmentally sensitive biota. The Board's review of Pacific Coastal and Navigation Challenges, the theme of the meeting, will provide important future benefits to all the Pacific coast states, as well as to the US Army Corps of Engineers.

The SPD boundaries account for nearly one-fifth of the land mass of the United States. The State of California has a wide variety of commercial, recreational, and navigation facilities along its 1,200-mile coastline. In the civil works arena, the Division's major water resources missions are flood control and navigation, including shore protection.

In January 1988, an extremely strong winter storm lashed the southern California coast. Twenty-foot waves, on top of a 7-foot-high tide, destroyed or damaged over 200 homes and businesses and inflicted severe damage on boats, shoreside facilities, and automobiles. It also caused severe damage to Federal coastal projects. About half of the total damages occurred in Redondo Beach, where the Federal breakwater was overtopped and shoreside facilities were hard hit. The Los Angeles District mobilized quickly and made emergency repairs to the breakwater in a very short time. The Board of Engineers for Rivers and Harbors has approved studies for raising the breakwater elevation, and funding has been authorized for preconstruction engineering and design. The Corps is moving ahead with this important coastal project for Redondo Beach.

Coastal engineering is facing increasingly complex issues as the Nation moves into the 1990's. The problems the Corps now faces and expects to face in the future are complex and require sound technical solutions. The Board members are the Corps'

experts in reviewing programs relating to coastal engineering research and development (R&D), recommending areas for particular emphasis, or suggesting new topics for study.

The Chief of Engineers' Vision Statement has laid out a framework to take the Corps well into the next century. The SPD is developing its own vision for the future so that it is not only in sync with the Chief's vision, but is also bringing into sharper focus its own vision of how it can better serve the people in this most dynamic region of the country.

Because the Corps is in an era of extremely constrained resources, each of us must share our ideas and experiences throughout the Corps community, optimizing the special engineering talents and skills of our people and our individual organizations, if the Corps is to remain in the forefront of engineering design and construction for the Nation in the century ahead.

LTC Glen F. Weien welcomed the Board to Los Angeles District. He said they had put together an ambitious program for the 52nd meeting of the CERB. The topics addressed by the speakers are extremely important, especially considering the challenges we face today in coastal engineering. He expressed his appreciation to the City of Redondo Beach for their support in hosting the meeting. He noted that there would be a tour of the Los Angeles coastal region that afternoon.

REVIEW OF COASTAL ENGINEERING RESEARCH BOARD BUSINESS

COL Larry B. Fulton,[1] Executive Secretary
Coastal Engineering Research Board
Commander and Director
US Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

There were several action items resulting from the last Board meeting in Wilmington. The list in Appendix B covers the status of action items from the Wilmington meeting and continuing action items from previous Board meetings. All other action items have been completed. We will continue to update the status of action items prior to each meeting and provide a list to the Board as read-ahead material. At the 47th CERB meeting in Corpus Christi, Texas, we were asked to formalize the action item list. A master list showing actions taken since the 47th meeting is maintained at CERC.

I will now cover the status of action items shown in Appendix B. Item 51-1 stated that the President of the CERB should have a dialogue with the Commandant of the Engineer School relating to training of military officers in the coastal specialty (establish an Army Education Requirements Board requirement).

Action item 51-2 directed us to report on procedures for transferring complex numerical models from the laboratory to our field offices, e.g., Beta sites. Beta sites are offices where people are recognized as having the knowledge and ability necessary for testing the model and providing feedback. CERC has committed to transfer these numerical models to the field through a Coastal Modeling System (CMS) originally based on the Corps' time-share system, but will be moved to the Corps' Supercomputer site in the Information Technology Laboratory at WES within the next few months. The objective of CMS is to make these complex codes as easy to use as possible. Plans are being made to use the same microcomputer as the new Automated Coastal Engineering System (ACES) platform for interface and graphics with CMS.

The challenges in transferring this type of model to the field are many. When a model is put into CMS, a workshop is held to teach field personnel how to use the code and provide them with the draft user's manual. After the workshop, the user's manual is finalized, based in part on comments from the users. We are investigating the use of Beta sites in helping to refine the released versions of the software, and we are drawing on our experiences in developing user friendly software for ACES.

One recent very helpful event has been the development of the Numerical Model Maintenance Program spearheaded by Mr. Jesse A. Pfeiffer, Jr., of the Directorate of

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* See Appendix A for biographies of speakers/authors.

Research and Development. This program provides funding for updating and improving the documentation. Perhaps more importantly, the program provides funding to answer user questions about problems that arise. Action item 51-3 directed us to report on the process used to integrate numerical and physical modeling. CERC feels that one of its most significant strengths as a laboratory is its ability to integrate numerical and physical modeling along with field experimentation. Physical model facilities are routinely used to develop data sets for evaluation or further development of numerical models. The recently developed capability to model beach profile evolution in a physical model will be used to help validate and refine numerical models of cross-shore sediment transport and beach profile erosion. Equally important, field data collected under the Monitoring Completed Coastal Projects (MCCP) program at Barbers Point, Hawaii, are going to be used to evaluate the performance of both numerical and physical models.

Action item 51-4 is concerned with establishing a mechanism to ensure visibility and use of other nations' data and experience, e.g., German breakwaters. CERC uses a number of means to stay abreast of developments in other nations ranging from personal contacts between CERC personnel and their foreign counterparts, to formalized exchanges of information. CERC has publications exchange agreements with universities and government agencies in 29 countries and receives much of the important information published worldwide in coastal engineering. Highly qualified foreign researchers sometimes make extended visits to CERC at the expense of their own governments, and this allows direct interchange. An experienced Japanese researcher is presently spending a year at CERC performing research in an area where the Japanese lead the United States in technology. His salary is paid by the Japanese Government. Similarly, over the past few years, CERC has had two Swedish and a Danish researcher in residence for extended periods, and countries such as Germany and Sweden have paid travel and living expenses for extended visits by CERC researchers to their countries.

Significant foreign travel and visitor restrictions placed on the Corps in recent years have made it increasingly more difficult to interact personally with foreign researchers. As a result of Congressional inquiries on Corps foreign travel, Corps offices including WES have severe dollar limits on foreign travel. Limits on travel by Corps researchers to foreign-based conferences, laboratories, and universities are isolating the United States and significantly restrict flow of technology to the United States. Furthermore, since WES is a military installation, foreign researchers must now submit requests through diplomatic channels at least 45 days in advance of the visits and receive permission by Army Intelligence to visit WES.

The Corps' program to develop an airborne laser system to perform bathymetric measurements is a graphic example of difficulties caused by these restrictions. The development of the system is being cost shared equally by the Canadian Government and the Corps. Much of the development is being conducted in Canada using Canadian technology. CERC is the technical manager for this multimillion dollar development, but must severely limit the travel to Canada to monitor contract execution. Similarly, the Canadians must go through a lengthy process to visit WES. Therefore, CERC's monitoring efforts on this important study are much less than desired or perhaps required.

Action item 51-5 concerned publishing Mr. John G. Housley's results from the follow-up studies on low-cost shore protection. Funds for publishing the results were not available until this FY. Action is proceeding within Headquarters, US Army Corps of Engineers (HQUSACE), at this time to publish the results.

In Action item 51-6, the Board asked how CERC ensured that the research program maintains a wider perspective than the immediate, short-term (snapshot) needs of the present. In an age of level or decreasing research funding, it is difficult to fund significant efforts that are not high-priority field needs. However, the coastal research programs are very fortunate in that their Field Review Group and Technical Monitors have consistently supported research whose benefit is in the intermediate to long term. Also, CERC staff participates frequently on panels, workshops, planning committees, etc., sponsored by other Federal agencies and academia in broader technical disciplines to ensure that our basic research needs are recognized and that we are aware of new areas that could be of benefit to the Corps. Likewise, our staff remains cognizant of issues such as the environment and climate change so that our research will be relevant to such issues.

Action item 51-7 is to determine whether the National Oceanic and Atmospheric Association (NOAA) or the Minerals Management Service is mapping coastal sand resources. If not, should the Corps establish a program to map the resources? In addition to those agencies, we have contacted the US Geological Survey (USGS). The USGS has a Hard Mineral Resources program in which they are surveying offshore minerals including sand and gravel. They have also been involved in a 4-year joint program with the Louisiana Geological Survey, related to coastal erosion and wetlands loss, which has included a survey of offshore sand resources. If the Corps participates in this type of effort, a logical source of funding would be the Field Data Collection Program. However, we are presently conducting a high-priority expansion of wave gaging on the east coast, Gulf coast, and Great Lakes.

Action item 51-8 concerned a review of the establishment of a Science and Technology Research Center (STRC). Immediately following the last meeting of the

Board, CERC sent a letter to universities involved in coastal research concerning the Board's discussions on an STRC. Information was included in the letter on steps required to propose an STRC, and CERC offered to work with any university proposing to develop a multi-university STRC. CERC indicated it might be willing to join as a member of an STRC.

CERC received inquiries from several universities. National Science Foundation (NSF) time limits to submit a proposal were very tight, and only one university consortium decided to submit a formal proposal this year to the NSF for a Center for Coastal Dynamics and Erosion. CERC joined a consortium consisting of the University of Delaware and the Massachusetts Institute of Technology. Researchers from the US Naval Academy and the New Jersey Institute of Technology will also participate. CERC will make its facilities available to the consortium and will work closely with them to transfer technologies and scientific advances developed through the STRC to the Corps. CERC researchers will serve as liaison contacts with each major research component of the Center's Program. Dr. James R. Houston will be a member of the three-person Governing Board of the STRC.

We will report on the fate of the proposed Center at the next Board meeting. Other university consortia can propose future STRC's in coastal engineering and sciences, and CERC will work with them.

Action item 51-9 directed us to include a discussion on determining coastal project benefits at the Fort Lauderdale, Florida, CERB meeting next June. That will be done.

Action item 51-10 concerned getting the coastal engineering specialty added to SKAP categories. The Personnel Office, HQUSACE, has previously stated that coastal engineering is too limiting a category and would do a disservice to employees desiring consideration in other categories such as the much broader Civil Engineer. However, we and HQUSACE technical staff plan to meet and discuss this matter further with Personnel Specialists to ensure their opinion is the correct approach. We will report on this item at our next meeting.

Older items on which action is continuing include the following:

Item 50-5 from the Virginia Beach, Virginia, meeting directed us to review the current HQUSACE design guidance on small storm surges. Recent erosion protection design problems have highlighted some areas where we need improvements in our technology to better address design procedures involving small storm surges and beach-fill designs. Those areas include small storm surges' possible long duration, frequent occurrence, alongshore variability, and cumulative effect. Areas requiring R&D consideration have been detailed in a letter from the Engineering Division, Directorate

of Civil Works, to the Chief of CERC. These areas will be considered in determining overall R&D priority.

Item 50-12 directed us to explore the potential for the Corps to share the execution of our coastal R&D responsibilities with coastal states. We previously reported that CERC was preparing a draft cooperative agreement with the State of California for data collection. That draft agreement has been forwarded to HQUSACE for approval. The agreement with the State of California will form the model for future agreements with other coastal states. We have requested that approval authority for agreements be delegated to the Commander and Director of WES.

Item 50-17 said the CERB should consider land-use issues. Land-use controls are a local government issue. The Corps has approached this problem through the National Economic Development (NED) test. If local government wants a project (and shares in the cost) and it meets the NED and National Environmental Protection Act criteria, we are normally in favor of recommending construction. The social issues must be settled by elected local officials.

Item 49-5 from the Oconomowoc, Wisconsin, meeting was to explore the possibilities and merits of establishing a Great Lakes Technical Information Center. A computerized Geographic Information System is being developed by the Great Lakes States and the Corps under International Joint Commission sponsorship. This system will contain map-type data on various coastal-zone physical and economic features. We have been informed by the North Central Division that this system will probably be operated by both the Corps and the States.

We have continued progress on the Education Initiative from the Board's meeting in Sausalito, California. The Coastal Engineering Education Program (CEEP) has now been finalized and is included as part of the Corps-sponsored long-term training program. As presently structured, this program will be offered once every 3 years, and the first session will start in late August 1990. The program is administered by the WES Graduate Institute (WGI) and is offered jointly by Texas A&M University and CERC. This is consistent with the charge of LTG E. R. Heiberg III to the CERB and CERC to use academic capabilities and the staff and facilities at CERC. Last week BG(P) Kelly sent a letter to all Corps Commanders announcing the program. A brochure with program details has been provided to Board members, and additional copies are available at the registration desk. We have also included this information in a special edition of our CERCular information exchange bulletin, and copies of that bulletin are also available at the registration desk. The brochure has been sent to coastal specialists within the Corps, to management within the Corps' Districts and Divisions, and to training branches in the Corps' personnel offices. The bulletin goes to over 2,700 individuals worldwide.

Individuals not wishing to take the entire 1-year CEEP may take the courses at the Field Research Facility (FRF) and at WES separately. The course at the FRF will be offered through the Corps' PROSPECT program administered by Huntsville Division. The courses at WES will be administered through the WGI. We have received tremendous support and outstanding assistance from the training offices at both HQUSACE and Huntsville. I would especially like to thank Ms. Shelia R. Dent and Dr. Beth Kerns, both at HQUSACE, and Mr. Jeff Seward from Huntsville, for the extensive time and effort they have put into this program. They have definitely gone the "extra mile" in helping us.

We are excited over the program and have already had numerous inquiries from the field. We look to the Board and others in this room to help make it a success.

We have continued progress on the ACES, which was originally presented to the Board at our meeting in Homer, Alaska, and which we have reported on at each meeting since then. The ACES version 1.04 was released to the Corps in August 1989, and that version will be released to the public in January 1990. Work continues on the next version (1.05) which, in addition to new applications, will contain graphics capabilities.

I am also pleased to report that San Francisco District recently presented WES with a framed picture of San Francisco and a plaque in appreciation of the good work WES has performed for the District. That work included a fast-track effort by CERC to perform model testing for the Fisherman's Wharf project. The District plans to submit the Fisherman's Wharf project for an award under the Chief of Engineers' Design and Environmental Awards Program.

REVIEW OF COASTAL ENGINEERING R&D PROGRAM

Dr. James R. Houston, Chief
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Vicksburg, Mississippi

At the fall meeting of the CERB, I traditionally present finances of the General Investigations (GI) funded Coastal Engineering R&D Program. The GI R&D is that portion of our program used to advance the state of the art in coastal engineering. Yesterday, Gramm-Rudman-Hollings was triggered, and none of us know exactly what that means to the GI R&D Program. What I am going to present are finances of this particular program without Gramm-Rudman-Hollings. With Gramm-Rudman in effect, there will be a reduction of about $300,000 in the Coastal GI R&D Program and about $1,000,000 in all of CERC's programs.

The Coastal GI R&D Program of about $5 million is part of a larger GI R&D Program of about $20 million, which covers all disciplines in the Corps of Engineers, that is, everything from structural engineering to environmental engineering. The overall GI R&D Program has had ups and downs over the last 10 years, and, basically, funding today is about what it was at the beginning of the decade, in actual dollars. With inflation taken into account, the purchasing power of that budget is down. Putting it into the larger context of the Corps of Engineers' civil works budget, the Corps has less money in FY90 than it had at the beginning of the decade. I believe the Corps had a larger budget in 1965 than in 1990, so there has been a long-term downward trend, although the trend has flattened out in recent years.

Funding for the Coastal GI R&D Program is less today than at the beginning of the decade in actual dollars. When inflation is taken into account, there has been a constant decline in purchasing power over the last decade, and today the purchasing power is half what it was at the beginning of the decade. Over the last several years, there have been extraordinary efforts to reverse this trend; and, in fact, to some extent it has been reversed. In FY88 and FY89, there was a slight upward trend.

Reversing the downward trend in funding has been like trying to paddle upstream. The 1980's have been a time of tremendous difficulties in the budget, and the ground rule of government has been to cut programs rather than increase them. Mr. Jesse Pfeiffer of the Corps' Directorate of Research and Development has tried to reverse this trend. First, he had to convince the Corps of Engineers that more money was needed in the GI R&D Program. This was not easy because the Corps' budget was declining in the early 1980's. He then, along with the Corps, had to convince the Office of Management and Budget (OMB) that an increase was needed at a time when OMB was

looking to cut funding. The OMB was eventually convinced that long-term R&D was needed to reduce future costs. The President's budgets have gone forward with an increase in GI R&D for at least the last half-dozen years.

There have been troubles in Congress obtaining increased funding for GI R&D. In 1986 and 1987, when our GI R&D budget hit its low point, the House agreed with the President's budget, but the Senate did not and cut the budget. In 1988 and 1989, we did get increases, due largely to the help we received from the Director of Civil Works, first LTG H. J. Hatch and then BG(P) Kelly. In this year's Congressional budget testimony, BG(P) Kelly spent a large portion of his allotted time discussing the GI R&D Program and presented five examples of where R&D in the program had really saved substantial amounts of money. Two of the five cases he presented were coastal related. His testimony was well received by Congress; however, this was a complicated year. There were other initiatives in the GI Program from the Assistant Secretary of the Army, such as the Construction Productivity Advancement Research Program and the Magnetic Levitated Train Program. The net result was our GI R&D Program did receive cuts this year.

In summary, times have been tough throughout the 1980's, and they are not getting any easier. It takes extraordinary efforts to increase funding in GI R&D, and we have been getting these efforts from Mr. Pfeiffer and BG(P) Kelly. The budgeting process is complex, and we do not know from year to year what is going to happen. We could have received a much worse cut than what I have shown here.

HUGO UPDATE--INTRODUCTION

MG Robert M. Bunker, Commander
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Hurricane Hugo came through the Virgin Islands on 17 September 1989, and St. Croix was particularly hard hit. This was a class 4 storm with winds up to 145 miles per hour over a wide front and with a very widespread sea surge of up to 17 feet. The area first hit, in the Virgin Islands, was a relatively undeveloped area with frame construction and corrugated metal roofs.

No one got into St. Croix until about 2 days after the storm hit. There was essentially no communication, and when assistance arrived in St. Croix, it was discovered that government had essentially broken down with the level of devastation and the loss of all facilities and infrastructure. There were no particular lessons from a coastal point of view. While there was a large sea surge, it did not appear to be terribly destructive of the beaches.

The next day, the storm hit Puerto Rico. The eye of the storm passed about 20 miles north of San Juan, going from east to west, and that greatly decreased the amount of damage from what could have occurred. Most of the infrastructure of Puerto Rico was put out of commission. Within about 4 hours of the Governor's request for assistance, the Corps of Engineers awarded its first contract, which was a water supply contract.

Hugo covered an area larger than the State of Georgia, so it was difficult to accurately pinpoint where the storm would hit. Thirty-six hours before landfall, it looked as if the storm would come ashore south of Jacksonville, Florida, and north of Cape Kennedy. Twelve hours before landfall, it looked as if it would come ashore at Savannah, Georgia. Savannah and the south Georgia and north Florida coasts were evacuated.

The hurricane actually came ashore in the late evening of 22 September right at Charleston, South Carolina, and then tracked across South Carolina, through Charlotte, North Carolina, and up into the western tip of Virginia. From the North Carolina/ South Carolina border down to a point about 15 miles south of Charleston, a distance along the coast of about 125 miles, the storm surge height was 12 to 20 feet relative to the National Geodetic Vertical Datum. Over that distance and to a depth of about 200 yards from the shoreline, there was 50- to 80-percent damage on an average. About half of the length is uninhabited; the other half is highly developed in tourist and recreation activities.

Hugo came across the barrier islands and devastated some of them, from the south end of Folly Beach south of Charleston on up about 15 or 20 miles into North Carolina. It came ashore with strong surge and violent winds and caused heavy damage, particularly just to the northeast of Charleston. There were significant areas of very high tree blowdown across South Carolina and North Carolina and great disruption to both primary and secondary power systems. The storm seems to have spun off a continuing stream of small tornadoes which touched down and cut off trees at an 8- to 10-foot height all the way up across the two states. About 35 percent of the trees were blown down in Charlotte, North Carolina.

The Ben Sawyer Bridge going out to Sullivans Island near Charleston is a swing bridge over the Intercoastal Waterway. The bridge was seriously damaged by the hurricane winds, but is now back in place. It will take approximately another 2 months to get the turning mechanism repaired so that the Waterway can be fully reopened to traffic. That bridge provided the only road link to get vehicles out to Sullivans Island and the Isle of Palms, which were devastated by the storm.

A great deal of damage was caused by the storm surge totally overflowing the barrier islands and dumping into the Intercoastal Waterway directly behind the islands. An enclosed marina was located directly behind the Isle of Palms. The surge across the island carried the boats out of the marina, across the Waterway, and onto the shore on the opposite side.

Damage to buildings extended to the second-floor level in some cases, so the surge broke through more than one floor. There was a lot of infrastructure damage behind the beach and damage to foundations, parking lots, and swimming pools; and recreation facilities between the buildings and beach were washed away.

Starting the first week in October, the Corps received a mission relating to the high lunar tide which occurred from 14-16 October. The duneline had been destroyed along 60 miles of the coastline between the northern border of South Carolina and Charleston. Normal high tide in the area is about 4 feet. The lunar tide had a maximum of 7.2 feet. A combination of the Federal Emergency Management Agency (FEMA) decision, resource and tasking, and a request for state assistance led to building emergency berms along the sea front for a total distance of about 40 miles. The objective was to protect the area behind the berms from more significant damage caused by the high lunar tide.

The South Carolina Coastal Council authorized beach pushing, bringing in sand from approved sand pits, and sand bagging as measures to be utilized for protection. We spent $2.8 million on the effort. We were very fortunate as we went through the high tide period and did not have offshore storms. The breaches in the protective

berms were small and isolated, and no significant damage has taken place behind them.

Most of the protection was for infrastructure. In Myrtle Beach, for example, the entire sewerage system is exposed, and we were concerned we would lose it if we had another flooding tide. Major facilities behind the beachline which were just being cleaned out would have been underwater again. The mission was a success in protecting the area.

(Discussion follows presentation by Dr. Stauble.)

HURRICANE HUGO--CERC ACTIVITIES

Dr. James R. Houston, Chief
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US Army Engineer Waterways Experiment Station
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Before describing CERC's efforts, I would like to compliment the Charleston District. Whereas some Federal agencies were criticized for their response to Hurricane Hugo, the Corps of Engineers was not. The Charleston District is a fairly small District. However, not only did Charleston District do a remarkable job, the public perception is that they did so. If the Corps gives some kind of "atta-boy" award, the Charleston District should receive it this year for a tremendous job in coping with Hurricane Hugo.

CERC had three teams of people out in the area immediately after the hurricane. One team measured high-water marks, a second nearshore profiles, and a third surveyed damages. We quickly learned that if you wanted to be able to phone somebody at any hour, have somebody be there who knew answers to your questions, and had electric power, you needed to call Emergency Operations at a Corps District Office. That was the case in Charleston. They always knew what was happening. They had to move their center once, out to an Air Force base; but they were always in operation, and you could always communicate with them.

I was in Charleston last week and saw the Corps preparing for the lunar high tide. The FEMA had determined which part of the coastline was in imminent danger and eligible for FEMA funding. The Corps of Engineers was given the task of carrying out the work, which involved constructing a dune system over many miles of coastline in a very short period of time.

In addition to Charleston District personnel, there have been many people from other Districts on loan to Charleston. Even the person from Jacksonville District, who is coordinating our next Board meeting, was in Charleston for a month, working to get the dunes up.

Originally CERC was going to send out just one team to make high watermark measurements. High-water measurements are needed because CERC routinely uses storm surge models to determine heights of seawalls, dune systems, and levees. It is necessary for surge height calculations to be very accurate because an extra foot of height for a seawall can be a very large cost. Being a foot too low also can result in disaster. There has not been a lot of data to verify accuracy and dependability of models. Many measurements made in the 1950's and 1960's were taken on an ad hoc basis by a variety of people, and often a considerable time after the hurricane.

The quality of high-water data goes down rapidly if the measurements are not made immediately after the hurricane.

With this in mind, we positioned a team in Fayetteville, North Carolina, and they were to go in at first light and begin making high watermark measurements. Making measurements was difficult, as roads were out, but the team was able to make a number of measurements.

Corps Districts usually make a variety of measurements following a hurricane. In our communications with the Charleston District and the South Atlantic Division (SAD), it was clear they probably would not be able to do so in this case because of real emergencies in South Carolina. The Division also was busy with emergencies in the Virgin Islands and Puerto Rico. CERC decided in coordination with the District and Division to send two more teams to the area to make further measurements. The SAD Engineering Division provided excellent support for the CERC team stationed at Myrtle Beach, South Carolina. The SAD Executive Office managed to obtain a US Army helicopter to enable the team to survey the entire coastal disaster area, especially those shorelines inaccessible by car.

We sent one team from the WES-CERC FRF in Duck, North Carolina, to make profile measurements because we had learned the South Carolina Coastal Council had taken profiles at Debidue Beach, and Dr. Timothy Kana of Coastal Sciences and Engineering, Inc., had made 77 profile measurements at Myrtle Beach this last summer. Profiles change little during the summer, so we knew if we could take measurements right after the hurricane, we could determine the effect the hurricane had on beaches and dune systems. Hurricane impacts on beaches and dune systems are important to the Corps of Engineers because project justification is based on flood protection or storm damage reduction. We need to know how high a dune needs to be, or how wide a beach, in order to survive a given storm surge and waves. In recent years, CERC has developed numerical models to look at dune erosion, but, again, there are very few data to verify the models. We mainly rely on data the Dutch collected for North Sea storms, and there are virtually no data available for hurricanes.

Of the profiles taken in the summer, survey monuments were lost during Hugo for all but 38 of the profiles. We made profile measurements for the remaining 38 profiles. The Board has been furnished copies of a draft report that presents about half of these profiles.

CERC also obtained aerial photographs through an existing contract we have to obtain aerial photographs when there are large storms near the FRF. We were able to get the contractor to work rapidly, making both infrared and visual aerial photographs along the beach and as far as 6 miles inland. We are sending copies of the

photographs to Charleston District and have been approached by other agencies for copies. The Federal Insurance Administration needs them for assessing damage, and the South Carolina Coastal Commission for its setback line program.

MG Bunker mentioned that Hugo was a class 4 Hurricane on a scale of 5. A class 5 hurricane, which is a superstorm like Hurricane Camille, would probably not occur as far north as Charleston because of cool ocean waters. After Hugo left Puerto Rico and started north, it weakened, and it looked as if it might not be much of a hurricane when it made landfall on the east coast. Then it started moving erratically and strengthening again. Hugo changed direction several times and appeared to be heading for landfall about 30 miles south of Charleston, until another direction change at the last moment brought the eye ashore at Charleston.

Because of the counterclockwise wind motion in a hurricane, the maximum winds and the largest surge and waves are on the right side of the eye as it moves forward toward the shoreline. The maximum winds for Hugo were about 30 miles north of the eye of the storm. If the eye of the hurricane had made landfall 30 miles south of Charleston, instead of passing directly over Charleston, the storm surge at Charleston would have been much higher.

CERC performed a computer simulation of Hurricane Hugo using a mathematical model called a planetary boundary layer model. The model generates winds that occur during the actual hurricane. Only spot measurements are made during hurricanes, whereas the simulation gives a complete wind picture. We can then use the simulated wind field to generate waves and storm surge using other models. The wind field was developed on a personal computer (PC) screen, using different colors to represent different ranges of wind velocity, and then a time-varying image on the PC screen was videotaped.

In the simulation of Hugo, you can see the hurricane leaving Puerto Rico and weakening, the path meandering, and then the hurricane strengthening. The winds start dying down after the hurricane makes landfall.

Using mathematical models, we can show what would have happened if the eye of Hugo made landfall 30 miles south of Charleston instead of at Charleston. We used NOAA's SLOSH model to simulate the surge. This model is fairly simple and not as accurate as the model we would normally use in project design, but the model illustrates basically what happens. Hugo actually produced maximum surge north of Charleston in a relatively unpopulated area. Our high watermark measurements gave a maximum surge of 20.3 feet above mean sea level. Simulating the same event, but with a landfall 30 miles south of Charleston, the entire City of Charleston would have been underwater. The actual measured surge at Charleston was 12.9 feet. The simulated surge for a hurricane landfall south of Charleston gives a surge height

greater than 20 feet. There would have been hurricane force winds and waves on top of the surge.

Charleston is a relatively small city, with a population of about 70,000. A 20-foot surge would have been even more disastrous for a larger city like Jacksonville, Florida, which has a population of about 500,000. The last 20 years have been a relatively quiet period for hurricanes, and people tend to forget past hurricanes. There is real potential for major disaster from hurricanes.

CERC's team that measured high watermarks stayed for a week and made a large number of measurements. A FEMA contractor arrived to take similar measurements as the CERC team was leaving. I can guarantee that, a week after the hurricane, the quality of the data was down significantly because of rain and activities of people to clean up. If high watermark measurements are not made right away, you basically do not get them.

Another agency that responded quickly was the USGS. We entered into an immediate agreement for a cooperative effort; they found all the monuments to determine vertical control for the measurements, and we surveyed. We already have much of the data plotted, and I have a map that shows contours of the surge based on our measurements. I mentioned earlier that the highest watermark we measured was 20.3 feet above mean sea level in the Bulls Bay area north of Charleston, a very swampy area.

The pattern of the measured surge is very similar to the simple NOAA surge model, so the numerical simulations are reasonably accurate. The surge heights in the model may be off by a foot or two.

(Discussion follows presentation by Dr. Stauble.)

HURRICANE HUGO--SHORELINE PROFILES AND DAMAGE ASSESSMENT

Dr. Donald K. Stauble
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CERC's damage assessment team consisted of three people, Dr. Lynn Hales, Mr. Bill Seabergh, and myself. Another team of four people from the FRF, under the direction of Mr. Bill Birkemeier, was responsible for reoccupying the surveys at Myrtle Beach and also managed to obtain some profiles at Debidue Island, which was closer to the area of the highest surge.

This presentation presents the impacts of Hurricane Hugo, particularly on the beaches and the inlets of the South Carolina coast. There are five Corps projects within Charleston District that are located in the area impacted. We were asked to assess damages that occurred along the beaches and also to look at the structures and other aspects of the projects. Some of the projects were beach fills.

Reviewing what happens when a hurricane makes landfall, the counterclockwise circulation of the wind and the forward momentum of the storm give the highest winds, waves, and storm surge on the right front quadrant of the storm's path. The left front quadrant of the storm has high offshore winds acting against the forward momentum of the storm, so it does not have the same impact on the shoreline.

As previously mentioned by Dr. Houston, the maximum observed surge height for Hurricane Hugo was 20.3 feet above mean sea level, and there were waves on top of that. The coastal dunes and buildings were no match for something of that magnitude. The barrier islands were completely inundated during the height of the storm.

The area of structural damage extended from Folly Beach in the south up into the North Carolina coastal area. We divided the study into three areas: the Grand Strand area, which is populated; the Cape Romain area, which is an unpopulated wildlife refuge and national forest area; and the Charleston area with the three barrier islands that sustained significant damage as the eye made landfall.

We started at Little River Inlet on the North Carolina/South Carolina line, within the Grand Strand area. At North Myrtle Beach, the surge height was around 12 feet above mean sea level. Measurements at a concrete seawall showed a drop in the beach elevation of 4 feet, indicating how much sand was lost from the beach. Small stone revetments failed, and the stones were scattered across the beach. Many wooden bulkheads had boards knocked out. Some seawalls stayed intact, but were flanked around the ends and/or overtopped, and the buildings behind them were damaged or

destroyed. This portion of the coast was 120 miles north of where the eye of the hurricane came ashore.

In Myrtle Beach, a beach nourishment project was completed in 1986. The project was constructed in four phases, and each area received a different amount of sand at a different time. The total project covered the entire shoreline of Myrtle Beach. The profile measurement crew reoccupied several profiles along Myrtle Beach and was able to get volume measurements. There was a mean loss of about 10 cubic yards per foot of beach in this area. It was variable along the beach and was probably dependent on the amount of sand that was placed before the storm occurred.

We will look in detail at three profiles, one at the northern end, one in the central area, and one at the extreme southern end of the project. There was some difficulty in obtaining the profiles because of heavy rains the week after the hurricane. The water was rough, but the offshore profiles were obtained using a Zodiac. The onshore profiles were obtained using a rod and transit.

There is a seawall at the central area profile, and all of the fill material that was placed in front of that seawall was lost from the beach. Much of the material was carried into the offshore area below mean sea level. The same effect was observed at Ocean City, Maryland, the previous winter when, during a northeaster, the fill material eroded away from the upper part of the beach, but was deposited in the nearshore area.

At the south end profile location, there was a dune area where the dunes were completely obliterated. Some sand overwashed into the streets which had been behind the dunes.

Moving south of Myrtle Beach and looking at the Garden City and Surfside area of the Grand Strand, there was extreme damage. Most of the storm impacts were from a complete overwash of a very narrow barrier island. The storm surge knocked the ocean front row of houses into the back row and in some cases three blocks back.

At Murrells Inlet, which is a Corps project, some of the dredged material had been placed on the beach north of the project, and some south of the project at Huntington Beach State Park. One area south of the inlet was completely breached and overwashed, and much of the sand moved down the coastline into the Litchfield Beach area. The jetties themselves, at least at the land end, were fairly well intact, including the macadam cap.

Moving south to Huntington Beach State Park, we observed a ridge of sand that had started moving back onto the beach again so that there was accretion occurring. That was 4 days after the storm, so there was a rapid recovery in that case, with the waves moving the sand back onshore. The project itself had a frontal dune that was completely flattened and a secondary dune that was breached at several points. The

surge finally stopped when it hit the tree line. There were some houses just to the south of the project which seemed to have survived fairly well, even though the dunes were gone.

Moving farther south, we looked at Litchfield Beach, Pawleys Island, and Debidue Island. The beach profile crew took some profiles on Debidue Island. The dunes were higher than 20 feet on portions of both Pawleys Island and Debidue Island, and those were the only dune systems we observed that actually survived. The dunes were severely scarped on the ocean side, but did survive as a structural entity. The houses behind them had little or no damage. The frontal dune stopped the surge, while on other parts of the island, where there was little or no dune, the island was completely overwashed. The beach was severely eroded, and again much of the sand was in the immediate offshore area.

A little farther to the south, the dunes were as high as 18 feet, and in some areas the dunes were able to hold back the surge, while in other areas the dunes were lower and, as a result, were destroyed. In some cases, houses sustained substantial damage from the surge. In one case, there was a well-constructed seawall topping at +8.2 feet which did survive, backed by a dune cresting at +18 feet, but the magnitude of the storm and the height of the surge at approximately 18 feet overwhelmed the area, removing the dune and damaging the upland structures.

To the south, in the Cape Romain area, the highest surge of 20.3 feet was measured. This is a relatively undeveloped area. The surge measurement was taken in the vicinity of the two mainland towns, McClellanville and Awendaw, located some 8 miles inland behind the marsh and low barrier islands. Looking along the beachfront, we could see where dunes had been completely flattened, overwashed into this marsh. Going farther south to the Bulls Bay area, there was an island where all the trees had been completely sheared off, and the island itself had migrated back as overwash carried the sand across the marsh surface.

In the Charleston area, where the eye made landfall across Sullivans Island and Isle of Palms, the surge knocked down cinderblock buildings that had not been well constructed. Sand from the beach was carried back about three blocks, and the entire Isle of Palms was overwashed. There were some well-constructed structures built on pilings which had minor damage, while other adjoining structures, not as well constructed, had major damage.

At Sullivans Island, the surge went completely across the island, resulting in substantial damage, depending again on how well the buildings were constructed. Sand was, again, carried up to three blocks inland by the surge. The ebb-tidal deltas at the inlets along this section of coast seemed to help in protecting some areas of beach from erosion.

At Folly Beach, south of Charleston, the major structural damage was in the central part of the island and at the north end where there was a breach. One row of houses was completely gone. A temporary road was constructed to reach the northern part of the island. The storm surge at Folly Beach had a height of approximately 10 feet.

About 20 miles farther south, at the islands of Kiawah, Seabrook, and Edisto Beach, there was very little damage. This is where the winds were coming offshore. The major damage was from Folly Beach north.

In summary, we found that where the large dunes held, there was less upland damage. Where dunes were gone, structural damage occurred in the upland areas. The beaches eroded along the entire study area, and in some cases the old marsh surface was exposed. Some of the sand went offshore, most of it back onto the island.

Coastal structures had varying degrees of damage. Most of the large ones survived, providing some degree of protection. Most of the smaller protective shore-front structures were completely destroyed with heavy damage to houses behind them. There was some overtopping of smaller structures that survived so that the upland structures sustained damage to their first-floor level. There was little or no apparent damage to the landward portion of navigation structures, such as the jetties at Murrells Inlet.

DISCUSSION

Prof. Dalrymple said he was very impressed by CERC's response. He asked what the follow-up would be on the beach profiles. Dr. Stauble said it had not been determined yet if CERC would go out again to remeasure the profiles, but there would be a more complete report as more data were analyzed.

BG Robert C. Lee said he also applauded the quick response. He asked what CERC would like to pass along on lessons learned, on timing of data collection, etc., that we should be thinking about the next time we have a major storm. Dr. Houston said to get high watermark measurements, teams have to be prepositioned. You have to have a team that is away from the ocean, because the area of landfall is uncertain. If you get too near the coast, you may get trapped there while the hurricane goes ashore somewhere else. From experience, we have had our groups stay inland, maybe 50 miles, and then move to the coast after the hurricane makes landfall. Dr. Stauble said that the heavy rain after the hurricane washed watermarks off the outside of buildings, so they had to go inside to get measurements. He also noted that many people were bulldozing the area immediately after the hurricane, even before the Corps got people into the area, so they immediately changed the shape of what happened in some areas. You have to get someone in, to take measurements, very fast. He said you need to take aerial photographs as soon as possible, and CERC's existing contract allowed us to mobilize a company very quickly to do that.

MG Bunker said one important thing is knowing what recent research has been done in the area under consideration, and obviously CERC had information that they included in their planning. That could be done to some extent in other cases,

depending on where you have a storm. Dr. Stauble said they had good cooperation from Dr. Kana. CERC knew about the projects and was able to coordinate with a representative from his company, and that person was out with the beach profile team.

Prof. Raichlen said he shared the view of others that CERC's response was really excellent. He asked how the response was set up and whether the same response could be initiated for other areas of the country. Dr. Houston said CERC made a decision to move, and the funding came from CERC Department Expense. He said CERC would try to get emergency operations funds, but, barring that, would take it from other funds. He said these are episodic events, and it is hard to have money available for something that occurs only once in awhile and is not predictable very far in advance. Basically, you just have to make a decision and act. Mr. Pfeiffer said that there is some flexibility that allows us to reprogram funds.

COL Wilson asked why the pre-Hugo profile surveys had been taken. Dr. Houston said they were done by the South Carolina Coastal Commission and a number of local communities. They are planning future beach-fill projects and needed baseline information. We suspect that the state and the local communities will take follow-up profiles.

Mr. John H. Lockhart, Jr., asked if the pre-Hugo profiles had been taken before or after the northeasters that occurred earlier in the year. Dr. Stauble said they were taken after the northeasters.

MG Bunker noted that Charleston District had two beach nourishment projects in the area, in the formulation stage, one at Myrtle Beach and the other at Folly Beach. If the two projects had been constructed, they would have been at the 5-year level of protection, 9 feet above mean sea level. The hurricane surge would have gone right over them. The projects that are ready to go are not projects that will protect from the level of storm that we had with Hugo, roughly the 100-year storm for that reach of coastline. The emergency protection put in following Hugo was at the 5-year level of protection, and again that would not protect against a storm of Hugo's magnitude.

MG Bunker said it would be worthwhile watching reconstruction on the South Carolina coastline over the next few years. South Carolina has recently enacted a law establishing a setback line. Under the law, structures that are at least two-thirds destroyed cannot be reconstructed if they are seaward of the setback line. With several billion dollars worth of damage along the South Carolina coastline, we can expect to see some amount of pressure brought to bear to overcome the requirement to abandon heavily damaged property. He said he thinks we will have an opportunity over the next couple of years to see which way public policy is going.

MG Bunker said he was proud of the Corps' response to Hugo. There were more than 500 Corps employees working on Hugo recovery, and over 200 of those were from outside SAD. The two primary backup Divisions were the Ohio River Division and the Lower Mississippi Valley Division. There were also a lot of people from the Southwestern Division, in particular Spanish speaking employees who were helping in Puerto Rico. There were also people from the Missouri River Division and from other Divisions. The SAD people managing the overall recovery feel that the quality of people who have come from the other Divisions is absolutely extraordinary.

MG Bunker is proud of the work in the San Juan area office in Puerto Rico, where LTC Stony Cox and his people have done a marvelous job. They got an emergency assistance contract underway and rapidly brought relief to the people prior to the Presidential declaration. They also provided a professional superstructure for recovery in the Virgin Islands.

LTC Jim Scott had been at the Charleston District for less than 40 days when the city was hit by Hurricane Hugo. That is about a 180-person district, which was increased to a strength of 400 with employees on loan from other Corps Districts around the country. They are doing a great job.

MG Bunker noted that there were 19 Corps families in the Charleston District who suffered heavy financial losses due to Hugo. Corps of Engineers employees from around the country have contributed money to provide assistance. They were able to have the first assistance delivered by the Sunday following the hurricane.

PACIFIC OCEAN DIVISION RESEARCH NEEDS

Stanley J. Boc, Jr.
US Army Engineer Division, Pacific Ocean
Fort Shafter, Hawaii

The Pacific Ocean Division's (POD) area of responsibility is within the Pacific Basin and is composed mostly of islands which in total area exceeds over 5 million square miles. Our present areas of responsibility include the State of Hawaii, the Territory of Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands. We also have reimbursable projects in areas outside of POD, such as Western Samoa, the Compact State (former Trust Territories) of the Republic of the Marshall Island, the Federated States of Micronesia, and the Republic of Palau. Over this vast area, the great variety of culture, economic and physical development, as well as remoteness, provides for an endless list of challenges.

The POD coastal research needs are as follows:

a. Directional deepwater wave data. Presently, and into the foreseeable future, our coastal engineers are still relying on Summary of Synoptic Meteorological Observations data. Recent discussions under the Wave Information Study (WIS) to upgrade the data to include the swell from the southern hemisphere and to refocus the grid system, so that our islands do not show up just as tiny dots, will prove valuable to POD. The change of the grid system must be accomplished to identify regional wave data on our islands.

b. Shallow-water wave data. Design guidance for depth-limited wave environments dictate our use of 0.78 d (water depth) for the maximum breaker height. Observations and limited research have shown that this ratio of 0.78 d is conservative and should probably range from 0.4 to 0.6 d. This would produce savings in project costs. The Corps of Engineers, through the monitoring of the Agat Small Boat Harbor, Guam, under the MCCP, has begun to address this need.

c. Design water levels. There has been very little emphasis on gathering data on design water levels. This information must be known before calculating a design wave in a depth-limited situation. We at POD have begun to gather computer-generated water levels from FEMA flood insurance studies and other site-specific studies, but these are not field checked against actual measured water levels.

d. Low-cost effective shore protection. Increasing construction costs and the administration policy on allowable project benefits have made the protection of the infrastructure of these small islands more and more difficult. Many times the protective reef is mined to provide the necessary armor stones for the protective structures. The POD needs additional innovative design guidance on low-cost but effective shore protection works.

e. Causes and prevention of long-period harbor oscillations. Some of our harbors have suffered from long-period surges. We need a better understanding of the causes and the prevention of these long-period oscillations.

f. Alternatives to borings for geotechnical information. With the tremendous expansion of development throughout our area, it is becoming almost impossible to obtain the necessary geotechnical information required for design

from borings. Many boring companies are extremely busy and are not interested in underwater borings, which are generally risky, and if they are interested, the cost is usually at a premium. The POD needs a reliable system other than borings to obtain this geotechnical information in a very shallow reef and deeper water environment.

DISCUSSION

Prof. Raichlen commented on long-period oscillations in basins. Preventing long-period oscillations goes back to the actual design of the basin itself. You cannot control too much once the basin is designed. Rather than talking about prevention, wouldn't it be better to consider how to alleviate problems? Mr. Boc said many of the harbors have surge problems. In Hilo Harbor, for example, the ship pilots have devised methods to deal with it. They have surge pilings they can tie up to during periods of surge, to keep boats from smashing into docks.

COL Wilson asked if there was any periodic monitoring to determine the physical and environmental effects of mining the reefs. Mr. Boc said there is no formal monitoring, but they do query local people after storms, and they have pictures taken by FEMA teams. They have found that the quarry pits aided in the prevention of erosion, but they are not sure of the reason for that. He thinks that the waves break on the reef, reform over the pits, and then break again. Some energy may be reflected back to the sea. Almost all of the mining is on the open-sea side, because that is the location of the harder rock.

REVIEW OF STATE OF CALIFORNIA BEACH EROSION CONTROL ACTIVITIES

William H. Ivers
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California Department of Boating and Waterways
Sacramento, California

The Department of Boating and Waterways has many responsibilities along the coast of California, including the development of small craft harbors and boat launching facilities and improvement of general access to the ocean. Another major concern is beach erosion control.

Historically, many of the Department's beach erosion control projects have been funded through the General Fund. Today, these projects increasingly are being funded through California's tobacco tax as well as other special funds, such as offshore oil revenues. Because money is scarce, critical projects are sometimes not funded immediately. The Department tries to budget $3 to $4 million each year for beach erosion control and shoreline stabilization projects.

At Crescent City, near the California-Oregon border, waves reflected from Whaler Island impinge along the shoreline, causing erosion. It was determined that installing a 450-foot groin at a 45-degree angle to the roadway would stop erosion. The groin was completed, and the beach is now accreting sand.

South of Crescent City near Eureka is the Buhne Point project, which was flooded during a 1981 storm. With only minimum protection provided after that storm, it was inundated again in a 1983 storm. Planning for protection was initiated, and $500,000 was appropriated. A sheet-pile bulkhead was put in to trap the sand, with riprapping on the inside. A US Army Corps of Engineers dredging project was being carried out concurrently, and the State was able to use the dredged sand as additional reinforcement behind the bulkhead walls. The Corps also received funding for improving this project, and Federal contributions provided for reinforcement of the bulkhead walls with more riprap. The Department received the California Partnership Award for private, local, State, and Federal cooperation on the project.

Demonstration projects in San Francisco Bay using the plastic tube were designed as part of the Corps' Low-Cost Shore Protection Demonstration Program. These projects did not work as well as expected. In the interim, sandbagging and rubble riprap were used to protect portions of the shoreline. After the demonstration program, the State was able to mine sand from the middle of San Francisco Bay, off Alcatraz Island, and transport it hydraulically to the Alameda beachfront for a 4,000-foot beach-fill project. A sand fence was constructed to hold sand in place, converting a threatened roadway with rubble riprap into a recreational beach. Sheet-pile terminal

groins were placed at the ends of the project to retain the sand in the project areas. Some $4 million in Department funds was provided to construct this project.

On the ocean shoreline of San Francisco, south of the Golden Gate Bridge, is the O'Shaunessy Seawall, which has provided adequate protection. South of Golden Gate Park, just downcoast of the O'Shaunessy Seawall, it was felt that onshore sand would protect the shoreline. That was true until the 1983 storm. Since then, the State, working with the City of San Francisco, constructed a seawall that extends down to bedrock, with riprapping in front, and a reinforced earthen retaining wall in back. That project extends 4,000 feet south of the Golden Gate Park. The Department's contribution to this seawall project amounted to $5 million over 3 years.

In Monterey Bay, the State constructed a seawall at Rio del Mar. Structures in the town are built below the bluff, and there is severe wave action. The 1981 storm caused considerable damage, and homes were destroyed. The Coastal Wave Data Program provided information that allowed the State to determine the needs of that particular area. A cantilevered H-beam wall was built prior to the 1983 storm, and although the storm overtopped the wall, the wall itself remained intact. Using data provided by the wave study, the State was able to build a structure that survived a 100-year storm. The cost of this project was shared on a fifty-fifty basis between the Department and local entities.

At Carlsbad, there was a severe bluff erosion problem; it was eroding at a rate of 1 to 2 feet per year. The State, in a joint effort with the City of Carlsbad, constructed a double seawall. This is a primary seawall, backed by a second wall in case the primary seawall is overtopped. There is also a retaining wall behind the seawalls because of bluff erosion. The project includes a 4,000-foot esplanade. The State worked with the Coastal Conservancy to provide additional access. The project won an architectural award. This project survived the January 1988 storm that caused severe damage in Redondo Beach. The Department's participation in this project amounted to about $3 million.

Between Surfside and Newport Beach is a beach replenishment project. Two million cubic yards of sand were placed at Surfside, and that sand feeds the littoral system that supplies sand to the beaches south to Newport Beach. This is a Federal, State, and local project for which the Corps provided the majority of funding.

The Department of Boating and Waterways is relatively small, with 55 employees. We try to standardize the design of projects as much as possible. Assistance from Scripps Institute of Oceanography in La Jolla and other universities helps us ensure our policy of commitment to an academic level of research with practical applications. An example of this kind of practical research is the Wave Gage Network, a wave statistics gathering system originated by the Department and now used cooperatively

with the Corps of Engineers to collect nearshore and deep ocean wave data. With our combined resources and dedication, we can get the job done. It takes hard work and a great deal of study; but working together, we can find protection not only for the coast of California, but for the coastline of the United States as well.

I appreciate the opportunity to address you on the Department of Boating and Waterways' role in beach erosion. We look forward to the continuing cooperation between the Corps and our department in serving the citizens of California.

DISCUSSION

Prof. Dalrymple asked about project monitoring. Mr. George A. Armstrong said they make periodic visits to the projects to ensure that they are functioning properly, but they do not take profiles and other data.

SOUTH PACIFIC DIVISION COASTAL ENGINEERING RESEARCH NEEDS

George W. Domurat
US Army Engineer Division, South Pacific
San Francisco, California

The California coast--redwood-covered mountains and rocky headlands plunging to the sea, rolling coastal hills, wind-blown dunes, and warm sandy beaches--all characterize the spectacular physical diversity of this Pacific shore. Uses of California's coastal resources are as diverse as its features, from small-craft fishing and recreational harbors to commercial shipping ports handling millions of tons of cargo each year; from fog-shrouded beaches along the northern coast, to palm-lined southern California beaches catering to millions of visitors annually.

To the US Army Corps of Engineers, SPD, the 1,100 miles of the coast of California means a continuing involvement and dedication to the management and preservation of this unique resource. This task is accomplished through full and effective planning, engineering, construction, monitoring, and maintenance of all Corps of Engineers coastal activities.

The Coastal and Navigation Program for SPD includes a variety of studies and projects involving small-craft harbor and large-port maintenance and improvements, shoreline protection, and coastal data collection activities totaling more than $25 million for the FY90 program.

However, with this large-scale program comes the need for significant improvements in our understanding of west coast processes and their interaction with our coastal structures and projects. Four major research areas are identified as critical in expanding our planning, engineering, construction, and operation/maintenance capabilities. These are (a) defining the impacts of major coastal structures on the surrounding environment, (b) increasing our knowledge base on shelf-beach-estuary sediment transport interactions, (c) validation and calibration of coastal processes models, and (d) increasing our understanding of basic oceanographic processes that are unique to the west coast.

Realistic analysis of our coastal and navigation problems and the high-quality solutions demanded by our cost-sharing partners can be realized only if the research necessary to define the processes affecting our structures is accomplished.

FIELD TRIP

Mr. Arthur T. Shak of Los Angeles District gave a briefing on the field trip. The tour then proceeded by boat along the coast north of Redondo Beach. The tour passed by the repaired breakwaters at Redondo Beach. Mr. Gregg Woodell gave a short talk on the El Segundo beach fill which was placed by the city and county of Los Angeles. The beach fill was created by using excavated material from the construction of the Hyperion wastewater treatment plant. The material was moved by conveyer belt by jacking a tunnel under the coastal highway and building a bridge over the coastal bike path, so there was no interruption to traffic.

The next project up the coast was the Federal project at Marina del Rey. This project has a dredged boat basin and a detached offshore breakwater.

The tour then proceeded to the area of the Santa Monica breakwater, which was constructed by the City of Santa Monica in 1934. Over the years, the breakwater has deteriorated, and it is being considered for rehabilitation. The pier behind the breakwater is under reconstruction.

The tour then returned south to view the coast along the Rancho Palos Verdes area. There is a land instability that has caused continuing problems for roads and houses in the area. The tour proceeded past Cabrillo Beach at the foot of the San Pedro breakwater. The beach and most of the parking lot were completely washed away by the January 1988 storm.

Messrs. John F. Warwar and Dwayne G. Lee joined the tour at the Port of Los Angeles and provided information on planned expansions in the Ports of Los Angeles and Long Beach, as the tour proceeded through the port area. The tour terminated at the *Queen Mary* in the Port of Long Beach.

IF EVERYBODY HAD AN OCEAN. . .

Robert W. Caughlan
President
The Surfrider Foundation
Menlo Park, California

Surfing is an ancient sport. The oldest historical records of surfing go back to a Hawaiian petroglyph that was carved on stone nearly 700 years ago. There are ancient Hawaiian chants that sing of surfing heroes and heroines that lived 500 years ago. When Captain Cook visited the islands in the 1770's, the first entry in his ship's log was about surfers. A hundred years later, Mark Twain in his book Roughing It also wrote about Hawaiian surfers and his own experience in trying surfing.

I have been involved in the environmental movement for many years in a number of capacities and have long believed that one of the major reasons California has such a strong environmental movement is that so many of the people raised here have so many different opportunities to develop some kind of special relationship with nature. Kayakers, rafters, backpackers, climbers, and hikers develop that kind of relationship with the mountains and rivers. Surfers, sailors, wind surfers, skin divers, fishermen, beach walkers, and coastal engineers develop a special relationship with the coast.

I was raised by the ocean on the San Mateo County coast and started surfing in 1960 when I was about 15. At that time, there were about 1,500 surfers in the entire State of California. Today, Surfer Magazine estimates that there are about 1.5 million surfers in California, 600,000 in Japan, and 4.5 million worldwide. It has become a big business. The surf and beach lifestyle industry is a $3 billion-a-year international industry. Most of that is in California, and it is an important part of the California economy.

For the past 3 years, I have been the president of The Surfrider Foundation. The foundation is a California-based organization with a rapidly growing national and international membership that has doubled each year. We have members in Israel, Italy, Australia, Colorado, and Hawaii. We publish a periodic newsletter, Making Waves. Part of the reason the organization has grown so fast and has been successful is that it is probably one of the only environmental organizations in the country that has the strong backing of a large and increasingly powerful industry with a totally self-enlightened, positive, and healthy vested interest in a clean ocean environment.

The Surfrider Foundation has brought a whole new constituency to the coastal agenda tables, and we think there are things we can contribute to the discussion. We have formed alliances with other environmental groups to work on different issues. Most recently we joined with the Amigos de Bolsa Chica at Huntington Beach in a

fight to save the wetlands, and we successfully stopped the Bolsa Chica breakwater project. We saved 3 miles of some of the most popular surfing beach in the area. We just won a 2-year legal battle with a home developer in Santa Barbara who wanted to cut off public access to one of the most popular surfing beaches in Santa Barbara at Hammond's Reef.

We are confident we will help obtain some long overdue environmental law and order at pulp mills in northern California, and the Environmental Protection Agency (EPA) has joined us in a lawsuit. We think we will help clean up the water in Humboldt County. We are working to stop the use of the ocean as a bottomless sewage dump.

Surfers have always been active in all the beach cleanup activities. The Bodyglove, a sportswear company which got its modest beginnings in Redondo Beach, is now a multimillion dollar operation. In 1962, the owners of the Bodyglove company organized a harbor cleanup right here in Redondo Beach and had 500 skin divers and surfers cleaning up the beach and the bottom of the harbor.

The Surfrider Foundation has just concluded an arrangement with the California Coastal Conservancy to take some of the management responsibilities for a trail to the ocean at Moat Creek in northern California, and we are looking forward to doing more of that kind of thing. The foundation is spearheading an effort to design the first human-sculpted surfing reef near Ventura, California.

Surfing beaches are crowded, and 97 percent of the injuries result from being hit by a surfer's own board or someone else's board. In the 50-mile coastline of San Mateo County, there are only about 2,000 yards of surfing beach, and only about 200 yards of beach is surfed on a regular, year-round basis. At present, surfing beaches are really very few and far between. There are 225 surfing spots in California to serve the 1.5 million surfers.

When surfing was a young sport, some good surfing was lost because of coastal development. The Surfrider Foundation does not intend to let that happen in the future. They have every intention of being a participant in the coastal discussion and coastal debate from here on in, on every important surfing beach in the country.

While some surfing waves have been lost, some of the best surfing waves have been created unintentionally by the construction of jetties, groins, and breakwaters. Surfers will be the first to give the Corps and coastal engineers credit for creating lots of surfing opportunities over the years. These include the Wedge in Newport Beach, created by the mach-stem reflection from the jetty, which is a great body-surfing spot; the Huntington Beach pier, where they have a world class surfing championship every year; the Surfside jetty project; and the great surfing wave created by the El Granada breakwater in San Mateo County.

The Surfrider Foundation has started looking for projects where they can create or improve surfing. There is a possibility at Charthouse Point, just south of Malibu. The sand replenishment program has tremendous potential. We are interested in working with the Corps on projects that would have multiple benefits, such as beach erosion control, fish habitat, and surfing. We are already doing some fundamental research on our own. The foundation would like to have the Corps consider surfing as a major side benefit to some of the erosion control projects. The potential is there.

Work is starting on the Surfside jetty. We would like to work with the Corps on that. The sand replenishment at Bataquitos Lagoon is another possibility. We want to be in the vanguard of this kind of positive research. We have done first phase engineering for a surfing reef at Emma Woods State Beach in Ventura, and we are going to start into modeling studies. As we progress, we will look forward to sharing whatever information and knowledge we gather.

To clean up the ocean and protect the ocean may sound like a pretty high and idealistic goal when you have a group of surfers; but our attitude is that nothing important is ever accomplished unless people are willing and able to think big and then are willing to work hard to make those thoughts into realities. To quote Senator Carl Schurz, a friend of Abraham Lincoln, "Ideals are like stars. You will never succeed in touching them with your hands, but like seafaring man on the desert of waters, you choose them as your guides, and following them, you will reach your destiny."

THE CRESCENT CITY PROTOTYPE DOLOSSE STUDY

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Introduction

Breakwaters are critical to the safety of many world ports. The high cost of building and maintaining breakwaters makes it imperative that their design and construction be efficient and that the cost and frequency of rehabilitations be minimized.

Within the last two decades, there have been many breakwater failures throughout the world. Many of the serious breakwater failures have been attributed, in part, to structural failure of concrete armor units. The large unreinforced slender concrete armor units used in high-wave environments are particularly susceptible to damage since the self weight consumes most of the structural strength of the units. The poor performance of concrete armor units has led to a resurgence of interest in developing a rational concrete armor unit design procedure.

Prototype Measurement Program

In 1985, CERC, WES, began a long-term program to develop a rational design procedure for concrete armor units. As part of this program, strain data were successfully collected from 17 38.2-tonne (42-ton) dolosse at Crescent City, California, during the period from January 1987 to May 1988.

The loading on the armor units can be characterized as either static or dynamic. The static loading includes self weight, wedging forces, buoyancy, and temperature effects. The dynamic loading consists primarily of hydrodynamic wave loading (pulsating loads) and impacts due to armor unit rocking. The scaling laws are different for static, pulsating, and impact responses of dolosse, so each of these loading categories was considered separately in the Crescent City prototype measurement program.

Local and offshore waves, the hydrodynamic pressure within the core and at the toe of the breakwater, boundary conditions in the armor layer, and dolos position and orientation were also measured at Crescent City. The intensive survey scheme at Crescent City using aerial photography and photogrammetry, land surveys, and underwater sonar also includes measurement of global movements and breakage of dolosse.

Prototype Results

Analysis of the prototype dolos pulsating structural response included reducing the two measured moments and a torque to a single resultant de-meaned stress. The maximum stresses from each record for all storms and all dolosse were combined into bins of constant $H_{1/10}$, and the resulting distribution of the maximum principal stress was found to be well described by the Rayleigh distribution, with the mean of the maximum stress as the single parameter. This maximum stress mean is linearly related to $H_{1/10}$ by a factor, k, that can be determined in the physical model. The result is that a designer can determine the maximum design pulsating stress, given an exceedance probability, a design $H_{1/10}$, and k.

The prototype dolos static response shows that self-weight and wedging-induced stresses in the 38.2-tonne dolosse can approach the critical concrete tensile strength, leaving no residual strength to resist pulsating and impact loads. Also, these static stresses increase with time due to nesting-induced wedging loads within the armor matrix. Finally, it appears from the prototype data that the dolosse respond to tide even when completely above the water level and that the magnitude of this tidal response can be a significant fraction of the self-weight response.

Supporting Models

As part of the development of a concrete armor unit design procedure in the Crescent City study, a load cell was validated as a tool for small-scale model dolos structural response measurement. To accomplish this validation, prototype conditions were closely duplicated in the physical model and the resulting model stresses compared with those of the prototype. The spectral parameters of a single significant prototype Crescent City storm were chosen to be modeled in these tests. The local bathymetry was modeled, and the time series, as determined from the storm spectra, were run for a single direction. The instrumented model dolos boundary conditions and orientations matched the prototype conditions closely. The mean of the maximum pulsating principal model stress showed very good agreement with the prototype. Also, for constant $H_{1/10}$, the distribution of the maximum principal stress was well described by a Rayleigh distribution, as in the prototype. Finally, the mean maximum pulsating principal model stress was linearly related to $H_{1/10}$ as in the prototype.

Analytical and numerical models were also developed as part of the Crescent City study. Numerical models were developed to approximate the wave forcing function and the resulting structural response. The resulting dynamic response of the dolos was modeled using a nonlinear Finite Element Method (FEM) model. Calibrated FEM

models have also been used to determine the maximum dolos stacking depth, the critical size at which the dolos strength must be considered, and the effects of increasing waist ratio on structural capacity.

Application to Dolos Design Procedure

The results from the above studies have been incorporated into a dolos structural design procedure. Both the loading and the boundary conditions are stochastic in the breakwater environment, so the Crescent City dolos design procedure is based on determining a design stress from exceedance probability distributions. Each of the static, pulsating, and impact loading categories is considered separately in the dolos design procedure. The stress exceedance distributions from each loading category are combined into a single design exceedance distribution. The designer can thus determine a design stress level in the dolos given a design probability of exceedance. The designer can then compare this stress with the material strength and adjust the dolos design as necessary to get a stress within the allowable stress level.

The design procedure is divided into preliminary, intermediate, and final design phases. In the preliminary dolos structural design phase, the dolos design stress is determined as part of a desk-top study. Within the intermediate dolos design phase, the dolos structural response is measured in the physical model using the load-cell technology. The final dolos design consists of combining the measured model stress exceedance distributions into a final design stress distribution and using this design curve to calculate a design stress level in the dolos.

Conclusion

This study has been successful in collecting prototype dolos structural data in the very harsh North Pacific coastal climate. The data have been used to validate a physical model structural response measuring tool and several numerical dolos models. The results of these efforts have been published in many conference and journal articles, and the final Corps technical reports will be published during 1990. The Crescent City dolos design procedure will also be published in 1990 and will provide safe design recommendations for dolos design at Crescent City. The design procedure will also provide a template for a future, more comprehensive concrete armor unit structural design procedure.

Future Efforts

A new work unit under the Corps' Coastal Research Program is using the results of the Crescent City study in the development of a more general concrete armor unit structural design procedure. Current work within this work unit includes a joint parametric physical model study with Aalborg University, Aalborg, Denmark. In this study, dolosse of three different waist ratios have been instrumented with load cells, and the dolos response is being investigated for various wave and structural conditions. This study is supplemented by a parametric numerical modeling effort to investigate dolos shape, material properties, reinforcement alternatives, and various other parameters. The results of these efforts will be used as an immediate update and generalization of the Crescent City dolos design procedure. This updated design procedure will be published in 1991.

DISCUSSION

Prof. Dalrymple noted that the failure of dolosse has been a very significant problem around the world. CERC has obtained a remarkable data set and a very nice analysis technique and design approach. He asked how the results would be published. Mr. Howell said the results have been published primarily in conference proceedings, such as the International Coastal Engineering Conference held in Spain and the International Association of Hydraulic Research Conference in Ottawa. There is an American Society of Civil Engineers symposium planned on structural problems in concrete armor units, which will be held at the WES. Summaries of the final results will be published in refereed literature.

Prof. Reid said this is an excellent example of how a well-planned and executed research program can lead to a real breakthrough in design. He said there should be a high priority for future investigations to follow up on this research.

Prof. Raichlen said, as an experimentalist, he has been very excited about the study. He said it has been quite remarkable to be able to obtain good data in both the field and the laboratory. This involved solving some very difficult instrumentation problems. It is an admirable result to be able to work this into a design procedure.

Prof. Raichlen noted there are limits in the number of instrumented dolosse that can be used. He asked how someone would proceed to get a complete design for a dolos structure. Mr. Howell said that they were still working to get the answer. He said there are a static question and a pulsating load question. They have found, in a gross statistical sense, there is little variability between boundary conditions and the position up and down the slope. The work that needs to be done is parametric studies where the instrumented dolosse can be moved around to different types of positions on the breakwater. If the statistical distributions hold for these other variations, then the cost of modeling should be minimal. If they do not hold, then additional tests will be required. The Crescent City breakwater has a very flat cross section, so that effect needs to be investigated. They are encouraged by the results to date.

COL Wilson asked how the physical shape of the dolos was determined and how we knew we were using the right shape. He also asked how the dolosse were placed on the breakwater. Mr. Howell indicated that had been determined through past experience and laboratory testing. He noted that there are many variations on the shape that have been used around the world. The Corps bases the shape selection on

past experience. Placement of the dolosse is still random. It is a random structure with random loads, which is a new field to structural analysis. Engineers would not normally set out to design a structure that is held together by frictional random boundary conditions and subjected to random loading.

Prof. Raichlen asked if any study was planned to look at elastic modeling problems to give attention to impact in the physical model. Mr. Melby said the second phase of a planned study would be a large-scale physical model to measure structural response for static, pulsating, and impact loads, using concrete armor units with the elasticity scaled. Those units would be instrumented and tested in a large flume.

Dr. Choule Sonu said he had been involved in the design of a breakwater in Algeria that failed about 10 years ago. During the model testing for hydraulic stability, model tetrapod armor units were rocking, and that worried him because armor unit strength was not being modeled. That required a professional judgment on what to do. He suggested two possible approaches, one conservative and one unconservative, where the number of rocking dolosse were taken as a damage ratio. The client adopted the unconservative approach, and the breakwater failed. That type of experience has weighed on his mind, and he is pleased that CERC has the vision to investigate this and has been so successful. The design procedure has to, somehow, incorporate the rocking behavior of the armor units.

COL William J. Reynolds asked what happens when part of the dolos unit fails. Mr. Howell said that one of the instrumented dolosse broke during initial placement and was left in place, and there has been very little effect over the 3 years CERC has been taking data. Tom Kendall of San Francisco District has been carrying out a photogrammetry study of armor unit movement, and in some cases broken dolosse have no effect, while in other cases broken dolosses move and cause other dolosse to break, potentially causing an unstable situation. It is one of those things that is boundary condition dependent.

Mr. Pfeiffer asked if future impact studies would set some boundaries on how much movement would be allowable. Mr. Melby said that impact response is a threshold criterion, i.e., you do not get impact until you get hydraulic instability and armor units start to move. They are working to develop some exceedance design curves based on stress versus some wave criteria beyond the threshold. They have not gotten to that point yet, so they do not know exactly what they will develop.

BG Lee indicated to Mr. Pfeiffer that in the budget development and justification, he make sure that all who need to know, know of the CERB members' recognition, acknowledgment, and endorsement of the need for further research and development in this area.

OCEANSIDE SAND BYPASS SYSTEM

Honorable Larry M. Bagley
Mayor
City of Oceanside
Oceanside, California

The construction of the Oceanside Sand Bypass System marks the culmination of more than 5 years active legislative involvement, public participation, and technical efforts from top experts within the Corps of Engineers and the coastal engineering field as a whole. This presentation describes how the sand bypass system evolved as a locally initiated beach erosion control and harbor maintenance project, reports on the successes of the system to date, and suggests some ideas on how this process might be applied in other areas.

The City of Oceanside is located on the southern California coastline about 30 miles north of San Diego. During the city's early years, the beach was wide and free from rock. Then, in 1942, Camp Pendleton Harbor was constructed immediately upcoast of the City of Oceanside without any regard to its effect on the littoral transport. The harbor jetties caused the immediate downcoast erosion of Oceanside's sandy beach.

Congress ultimately accepted 100-percent Federal responsibility for restoration of the Oceanside beach and maintenance of the Camp Pendleton harbor. However, despite nourishment of about 8.8 million cubic yards of sand between 1962 and 1981, the beach again disappeared. In 1981, the City of Oceanside developed a two-pronged strategy for solving the beach erosion: (a) to initiate the immediate replenishment of the eroded beach to protect against property damage and (b) to vigorously press the Corps of Engineers to proceed rapidly with the installation of a sand bypass system. The proposed bypass system consists of a series of fixed jet pumps and fluidizers in the harbor entrance with an additional jet pump for removal of sand from the accretion fillet on the north side of the harbor jetty. Both systems are powered by a barge-mounted pump house. A pipeline discharge system distributes the sand along the downdrift beach, a distance of about 1 mile.

A major benefit of the Oceanside experimental sand bypass system is the opportunity for scientists and engineers to learn more about the littoral processes at Oceanside and to develop new technologies for harbor maintenance and beach erosion control which could have worldwide application. Bypassing has a number of advantages over conventional dredging. It is less disruptive to recreationists both in the harbor and on the beach. By emulating the continued flow of sand provided by nature, many experts believe the bypass will be more effective in stabilizing the beach

than periodic dredging, which creates a large "bulge" of sand that is subject to accelerated erosion. More importantly, by avoiding the costly mobilization required by dredges and using the relatively energy-efficient jet pump, the bypass has the potential for significant savings over conventional dredging.

The initial development phase of the sand bypass has been in operation since June 1989. The north fillet jet pump is operating even more efficiently than the Corps of Engineers had anticipated. The two fixed jet pumps in the entrance channel are also operating successfully, although refinements are anticipated to increase the pumping efficiency in that location. Congress has appropriated monies to begin installation of fluidizers in the entrance channel during FY90. The fluidizers, which will expand the capture radius of the jet pumps, are the key to the maximum operational efficiency of the system.

COAST OF CALIFORNIA STUDY

Dr. A. L. Kadib
US Army Engineer District, Los Angeles
Los Angeles, California

The overall Coast of California Storm and Tidal Wave Study (CCSTWS) covers the 1,100 miles of California's coastline. It was divided into six different regions. At the present time, the study is focusing on the San Diego region, about 90 miles long, which extends from Dana Point to the Mexican border and includes Oceanside and Carlsbad. The main scope, which started in 1982, covers three main items: collecting field information, analyzing it, and presenting the analyzed information to different users.

The study looked at the sediment budget along the entire coastline of the San Diego area. That was done for different time spans. It also looked at shoreline movement and trends in movement. It looked at all available information from 1852 to the present. There are 57 profiles spaced along the coastline of the San Diego area at about 2-mile intervals. From that type of analysis, we can study the effects of sand nourishment, existing structures, and storms. We can tell local people why the beach width at a given location is changing and the reasons for that change.

The other item of interest is waves. This program, in combination with other programs like the California Coastal Information Program and WIS has put in a network of wave gages to study the variation of waves along the study area. In January 1988, southern California had a major winter storm. The CCSTWS allowed us to correlate the deepwater wave conditions with six different locations along the San Diego area coastline.

We were able to obtain a quantitative analysis of sediment motion between winter and summer and looked at a period between September 1987 and January 1988. We found that from summer to winter the waves can move an average of 50 cubic yards per linear foot of shoreline. That is very critical for future plans.

We have looked at island sheltering effects on the coastal wave climate. Los Angeles District has developed a coefficient to give a relationship between incident wave height and wave height in the lee of an island. The theoretical analysis is being checked at CERC to see if the design curves developed by the District need any modification.

The District has used CERC's GENESIS model to look at the effects of different structures on the shoreline.

The District has been trying to find a means of improving accuracy for estimating maintenance dredging along navigation channels. At the present time, we are using a

method that was published in the Proceedings of the International Conference on Coastal Engineering, 1976. It takes into account the sediment flow upstream of the navigation channel and the sediment flow in the navigation channel itself. The method has been applied to a number of existing projects.

The CCSTWS will use the results to produce a planner workbook for users. Ms. Pam G. Castens is the program manager for the workbook, and we plan to have that ready in early 1990. This is being coordinated with the San Diego Association of Governments [see Appendix C].

Work is almost finished for the San Diego region, and in FY91, the study will be expanded to two additional regions, the Orange County/Los Angeles County shoreline and the Monterey area. We are working with a master plan and believe that it is going in the right direction.

(Discussion follows the presentation by the Honorable Larry M. Bagley.)

COAST OF CALIFORNIA STUDY

Honorable Larry M. Bagley
Mayor
City of Oceanside
Oceanside, Californi

Mr. Rick Alexander of the San Diego Association of Governments (SANDAG) is handling most of the details coordinating work with the Corps of Engineers on the handbook mentioned by Dr. Kadib (see Appendix C). Dr. Kadib mentioned that over 40 different study reports have been issued so far. Most of the people who are associated with local governments are not educated as engineers. There was a need to reduce the technical reports to a publication that could be used at the local government level.

The SANDAG handles liaison with the CCSTWS through SANDAG's Shoreline Erosion Committee (SEC). The SEC is a technical committee which gathers this type of information and conveys it to the Beach Erosion Action Committee (BEACh) of SANDAG, which is the implementation tool.

The mayor of Del Mar, California, first brought some of the problems to the attention of SANDAG. They were trying some commercial devices to control shoreline erosion, and those devices did not work out. After discussion among coastal city representatives on SANDAG, they decided they did not have the information they needed. They did not know the sand budget in that littoral cell. They do not know what the primary motion is and the effects of the periodic storms they have. They needed a body of information that they could take to their local engineers.

A delegation representing local interests traveled to Washington, DC, and convinced their Congressional delegation that they should fund a study of the San Diego area coastline. They were able to get that enacted and obtained funding for the initial phase. Upcoast communities became interested, and the initial study has now grown into the Coast of California Storm and Tidal Wave Study.

The reports are invaluable for reaching a solution. The next step is to reach the engineering solutions we need, and after that, we need to reach the political and financial solutions that we need. The engineers need to tell us what we can actually do with the information, what is going to be beneficial in the analysis of our own local problems, and how much money we are going to need to get the required solution. We need to be able to present the required financial package and how we are going to put it together.

DISCUSSION

Prof. Raichlen said several years previously there had been a cooperative study between the California Institute of Technology and the Scripps Institute of Oceanography looking at the sand budget with a great deal of attention given to the inland supply of material to the coast. He asked if any of that had been incorporated into the study. Dr. Kadib said that the results of the study had been incorporated into the Coast of California Study, along with other work carried out at Cal Tech and Scripps.

Dr. Nicholas C. Kraus noted that the method mentioned by Dr. Kadib for estimating maintenance dredging was actually Dr. Kadib's method which was developed with his advisor, Dr. Hans Einstein, at the University of California. It is a very good, sophisticated method.

KING HARBOR (REDONDO BEACH)

Timothy J. Casey
City of Redondo Beach
Redondo Beach, California

The City of Redondo Beach and the Corps of Engineers have a relationship that goes back at least 50 years. The Corps was involved in the construction of the 1,470-foot stone breakwater at the entrance to the harbor in 1939. In 1958, the Corps extended the original breakwater 2,400 feet, raised the height to an elevation 14 feet above mean low low water (mllw), and constructed the 600-foot south breakwater.

The harbor had some damage from storms in the early 1960's. In 1964, the northern portion of the north breakwater was raised to an elevation of 22 feet above mean low low water. Even with those improvements, King Harbor has continued to be impacted by adverse storm and wave conditions. In the late 1970's, there was some preliminary engineering analysis for harbor improvements. The 1986 Water Resources Development Act authorized another harbor improvement project, and that process is nearing an end. The Act authorized raising the breakwater to a uniform 22-foot elevation and conducting additional planning, engineering, and design work to determine whether or not further improvements are needed.

The Redondo Beach King Harbor area is 50 acres of land and 110 acres of water. The area is owned by the city either in fee or in perpetuity on the basis of a 1915 grant of the tidelands and submerged lands by the State of California to the city. It is operated as an enterprise with the city as landlord. Over the years, the city has entered into 17 master leases to develop and operate the recreational and commercial assets known as King Harbor. There are 1,600 boat slips, 17 major restaurants, two hotels, three apartment complexes, and 100-plus small businesses. The harbor complex employs over 2,000 people. In 1987, the harbor generated $70 million in sales, $6.7 million in rents, royalties, and fees to the city, plus another $1 to $2 million in general taxes. The harbor accounted for 20 percent of the city's operating budget.

In the January 1988 storm, there was major damage to the harbor. This was the eighth of a series of storms that have affected King Harbor since the early 1960's and was by far the most severe. A section of the breakwater was breached. There was damage to the Horseshoe Pier on the south side of the harbor. Cattleman's Restaurant on the pier was badly damaged.

Going back to the north, to the central area in the harbor, a private sports fishing pier was damaged. The Blue Moon Saloon Restaurant was totally destroyed

and has not been rebuilt. That restaurant, before the storm, had an annual gross of $3 million dollars and provided the city with $100,000 annually in rental income. Nine people in the restaurant were injured when the storm broke through the glass windows overlooking the harbor.

On Mole C, Ruben's Restaurant suffered substantial damage. The revetment slope failed, and revetment stone was carried into the restaurant. The Portofino Hotel had just completed a $2 million rehabilitation; there was a failure of the balconies on the west side, and part of the south wing collapsed. There was substantial damage to the mole, which was almost breached. A boat that had been in the mooring area was washed over the mole into Boat Basin 2, north of the mole. There was substantial damage to boat slips, docks, and moored boats.

The harbor master's facilities are on the south end of Mole B. They were severely damaged. At the north side of the harbor, the Chart House restaurant, an apartment complex, the yacht club, and the yacht club parking lot were all damaged. There were seven or eight damaged sections on the northern end of the breakwater, but no complete breaches.

The sports fishing pier was damaged and weakened by the January storm, and a larger storm on 30 April destroyed a 300-foot section of the pier. The storm damages were compounded by a major fire in May that destroyed 60,000 square feet of pier deck and 20,000 square feet of improvements.

Some 22 months after the January 1988 storm, the economic losses can be assessed. In 1988, the gross revenues of the harbor enterprises dropped to $58 million, and the city's income to $6 million from $7 million the year before. There was $12 to 15 million worth of damage to private property, $2 to 3 million worth of damage to city property, and some $2 million in damages to the breakwater. Three hundred people were put out of work.

The area has recovered, and 22 months later, everything is back into operation except the Blue Moon Saloon and Cattleman's Restaurant. The Corps of Engineers did complete $2 million in repairs to the breakwater, restoring it to the prestorm condition plus some modest improvements. Planning and design work continues for the 1986-authorized project. Three million dollars worth of emergency repair work to damaged areas of the harbor and pier have been completed, including the dredging of King Harbor. Damage reimbursement money has been received or committed from FEMA and the State Office of Emergency Services. The city is confident that with continued cooperation between the Corps and the city they will be able to fund and construct the improvements to the north and south breakwaters.

MODEL STUDIES OF REDONDO BEACH KING HARBOR, CALIFORNIA

C. E. Chatham, Jr.
Chief, Wave Dynamics Division
Coastal Engineering Research Center
US Army Engineer Waterways Experiment Station

Introduction

Redondo Beach King Harbor, California, is a small craft harbor located on the Pacific coast at the southern end of Santa Monica Bay. It lies within the City of Redondo Beach, about 17 miles southwest of Los Angeles. Commercial, recreational, and sport fishing vessels serve local residents and visitors since the harbor is situated near productive fishing areas favorable to both sport and commercial fishing. It consists of about 55 acres of land and 112 acres of water and about 1,600 boat slips in three basins with a 77-acre mooring/anchorage area.

Development of the harbor started in 1937 when a 1,470-foot-long stone breakwater was constructed, but the harbor has undergone several modifications, improvements, repairs, etc., since that time. The south breakwater is 600 feet long and has an average crest elevation (el) of +12 feet. The north breakwater is 4,285 feet long and has an authorized crest elevation of +14 feet for its outer 1,600 feet (sta 36+00 - 52+00), and +22 feet between sta 15+50 and 36+00. Actual elevations for the two sections average approximately +14 and +20 feet, respectively. The shoreward end of the north breakwater has a rubble-mound section (el +14 feet) with a concrete Galveston-type seawall (el +20 feet). Wave protection baffles to the two northernmost basins (Basins 1 and 2) also have been constructed by the Federal Government. Maintenance of the breakwaters is a Federal respons ity, whereas, the City of Redondo Beach is responsible for maintenance of the wave protection baffles and the concrete Galveston-type seawall. The harbor entrance is formed by a 600-foot-wide opening between the breakwaters for small craft navigation. Natural depths through the entrance vary from 27 to 30 feet.

The Problem

Redondo Beach King Harbor is susceptible to frequent damages when large winter storm waves occur in conjunction with high-water levels. The energy of overtopping waves, waves passing through the harbor entrance, and wave transmission through the rubble-mound structures result in revetment damage, land erosion, flooding, and structural failure of facilities bordering the water. Some of these facilities include

hotels, restaurants, recreational facilities, and public and commercial buildings. Wave energy also enters the boat basins, causing damage to boat hulls, mooring lines, and docking and launching facilities. These adverse conditions also make Redondo Beach King Harbor an unsafe port of refuge during times of high tides and large storm waves, and the city has been unable to increase mooring space in the lee of the low-crested north breakwater. Although waves overtop the higher section of the breakwater during extreme storms and high tides, damage behind this portion is significantly less than storm damage behind the low-crested breakwater segment.

Average annual storm damages at the harbor are estimated at over $900,000, while damages associated with a 100-year storm event are estimated to total over $10,000,000. The most damaging storm to date at Redondo Beach King Harbor occurred in January 1988 with damage estimates of approximately $14,000,000. Some of these damages included destruction of substantial portions of three buildings; undermining of significant portions of revetment along the moles; sinking of six boats; damage to many other boats and piers; erosion of substantial land along the moles; damage to public parking areas, utilities, and fencing; and the loss of fueling facilities.

Purposes of Studies

Local interests have expressed a need for modifications to the breakwaters to eliminate excessive wave action in the harbor and damages to the surrounding businesses and to allow for additional harbor expansion/development. At the request of SPL, coastal hydraulic model investigations were initiated by CERC to:

a. Study and define wave conditions in the existing harbor.

b. Evaluate the adequacy of proposed improvement plans in reducing waves in the harbor.

c. Evaluate the stability, transmission, and general overtopping conditions for the proposed rehabilitation design.

d. Develop modifications to the proposed plan as necessary to provide the most economic and functional design.

Model Tests and Results

Prior to testing of the various improvement plans in the three-dimensional (3-D) model, tests were conducted for existing conditions to establish a base from which to evaluate the effectiveness of the plans. Wave height data, wave pattern photographs, and videotape footage were obtained for representative test waves from various test directions.

Similar data then were secured for 14 test plan configurations. Variations entailed changes in the cross sections, lengths, alignments and crest elevations of the southern arm of the north breakwater and/or the south breakwater.

Wave height criteria at various locations in the harbor varied for wave conditions with various return periods as follows:

Return Period Year	Mole C Sta 0+00-10+79 Wave Height Criteria, ft	Mole C Sta 11+00-20+00 Wave Height Criteria, ft	Mole D Sta 20+00-25+00 Wave Height Criteria, ft	Basin 3 Wave Height Criteria, ft
100	4.3	2.9	2.1	1.3
50	3.0	2.3	2.0	1.2
25	2.3	2.0	1.9	1.2
10	1.9	1.9	1.8	1.0
1	1.8	1.8	1.7	1.0

Based on the results of the 3-D investigation, it was concluded that:

a. Existing conditions are characterized by wave heights up to 8 feet along the moles for 50-year conditions.

b. The original improvement plan did not meet the designated wave height criteria.

c. Of 14 improvement plans tested, Plan 14 (Plan 5 from Stability Study) was considered optimal considering wave protection and construction costs. This plan involved raising and sealing a portion of the low-crested north breakwater and extending and raising a portion of the south breakwater.

Stability tests were conducted in a 300-foot-long, 6-foot-wide, 6-foot-deep wave tank. Local bathymetry was represented by a 1V:50H slope for a simulated prototype distance of 1,050 feet (30-foot model) seaward of the breakwater section.

Design waves were provided by SPL and were based on wave data collected at Begg Rock, California, on 17 January 1988 (located 75 nautical miles from Redondo Beach King Harbor). Twelve wave conditions were selected for testing with H_{mo} varying from 13 to 24 feet, T_p varying from 12 to 18 seconds, and still-water levels of 0 and +7 feet mllw.

Based on the results of the stability model investigation, it was concluded that:

a. Each of the five breakwater plans tested demonstrated acceptable stability for the sea side and rehabilitation sections for $H_{mo} < 22$ feet. Waves higher than 22 feet resulted in significant damage to the sea side.

b. Plan 5 (Plan 14 from 3-D study) yielded the best combination of stability, and reduction of wave overtopping and transmission through the structure. Any back pressure resulting from the filter layer included in Plan 5 did not cause significant damage to the sea side.

DISCUSSION

Prof. Raichlen asked if there were any plans at CERC to do 3-D models at a larger scale. Mr. Chatham indicated that CERC had done that for a model study of the Yaquina, Oregon, jetty rehabilitation. It is more expensive and more time consuming to do that.

Prof. Reid asked about the recurrence interval for the January 1988 storm and the tide stage when the storm occurred. Dr. Richard J. Seymour indicated that with only about 100 years of data, the projection goes off the end of the scale. Extrapolating with a Wybul Distribution that fits the data, the prediction is somewhere in excess of 200 years for the recurrence interval. An exact prediction cannot be reliably made. The peak of the storm and the maximum tide were not coincident, although it was a time of high tide so that the tide did have an influence. BG Lee noted that periods of record in the United States are relatively short compared with other parts of the world. Where the Chinese have records in some areas going back 1,600 years, the records in southern California go back only 100 years. Mr. Stephan A. Chesser noted that if a 200-year event occurred at one site, we need to determine exactly why those wave conditions occurred at that specific site.

Mr. Dan Allen asked that if the breakwater was being newly constructed, would the seal stone proposed for use on the back side be placed in the same location. Mr. Chatham said probably not; it would normally be placed in the core of a new structure. Mr. D. D. Davidson said the decision is dependent on space available for the volume of stone required. He noted that there are back pressure considerations, and the back side is probably better for placing the stone when rehabilitating the structure.

Mr. Thomas E. Mitchell noted that rehabilitation is normally to the points of the structure that have failed. He asked about potential repair to any failure of the rehabbed structure. Mr. Chatham said they have not looked at specific fixes for specific washout or damage points. He pointed out that the original San Pedro breakwater structure was stacked granite blocks, while repaired sections have been rubble mound. This was studied at WES, and the rubble mound is expected to be more stable than the stacked blocks.

Mr. John Hale asked about the wave heights that had been shown. Mr. Chatham said that the 2.1-foot value shown was the desired wave height criterion that the Los Angeles District proposed, while the 6-foot wave height was determined from a model study for the originally proposed harbor plan using a simulated 50-year storm event. The 6-foot height could also occur during some extreme events for the recommended plan. The model simulated incident wave heights up to 28 feet, which would be approaching the 200-year storm

HAWAII'S STATEWIDE SYSTEM OF COMMERCIAL HARBORS

Dan T. Kochi
Deputy Director
Department of Transportation
State of Hawaii

Hawaii's harbors, unlike most other jurisdictions, are owned by the State of Hawaii and are under the control of the Department of Transportation, Harbors Division. We provide the piers, yards, sheds, and internal roadways under nonexclusive use basis, and the terminal operators are required to provide their operating equipment and facilities needed for their operations. The operators provide their own reefers, offices, maintenance facilities, gantry cranes, and all cargo handling equipment.

Hawaii being an island state, our harbors are vital elements in the economic welfare of the state. About 80 percent of the goods consumed in the state are imported, of which 98 percent arrives by water transportation. Almost all of these goods first arrive in Honolulu and are then barged to the other populated islands.

Consequently, we operate our harbors as a Statewide System of Commercial Harbors consisting of seven deep-draft and two medium-draft harbors. The deep-draft harbors are Honolulu and Barbers Point Harbors on the Island of Oahu; Nawiliwili and Port Allen Harbors on the Island of Kauai; and Kahului Harbor on the Island of Maui; and Hilo and Kawaihae Harbors on the Island of Hawaii. The medium-draft harbors are Kewalo Basin on the Island of Oahu and Kaunakakai Harbor on the Island of Molokai.

Our harbors are not funded by the general funds of the state, but rely on our own income to finance our operating and capital improvement programs. Our operating budget for the fiscal biennium 1990-1991 is $66.5 million, and our capital improvement budget for this same period is $47 million.

On Oahu, where 80 percent of the state's population reside, Honolulu Harbor is the hub of our system. Almost all of the goods entering the state flows through this harbor. In 1987, about 9.7 million tons of cargo were accommodated, representing about 64 percent of the tonnage processed in the system. Our major container terminal is located at Sand Island and is utilized by Matson Terminals and Sea-Land Service. American President Lines' application to service the state is presently under review by the Maritime Administration. Their proposed terminal is envisioned at Pier 1. Supplementary cargo service between the US mainland and the state are provided by several barge companies, such as Hawaii Marine Lines and Sause Brothers.

Interisland service is provided by Young Brothers, which holds a State license for exclusive, regulated barge service.

Other vessels which call at Honolulu are our cruise vessels. The vessels of American Hawaii Cruises tour the islands on a weekly basis, departing from and arriving at the Piers 8-11 complex every Saturday. Additionally, we are starting a water transit system for Oahu. We awarded a contract to San Diego Shipbuilding and Repair to provide up to six ferry vessels. The vessel is a catamaran-type design with two hulls and a center platform, and it rides on an air cushion provided by centrifugal fans which blow downward against the water. The vessel will be capable of a cruise speed of 43 miles per hour.

Barbers Point Harbor is the second deep-draft harbor on the Island of Oahu. This harbor is located about 15 miles west of Honolulu Harbor and will enhance the shipment of goods to West Oahu. It is a major element in the development of the second city planned for West Oahu. We are currently constructing a 1,600-foot reinforced-concrete, pile-supported pier and 30-acre yard at a cost of $30 million. With completion of these facilities in June 1989, the harbor is operational. Concurrent with these State improvements, Hawaii Pacific Engineers is planning the installation of a coal unloader having an average operating rate of 918 tons per hour to feed a privately financed electric generating plant.

Our 2010 master plans have been completed for each of our neighbor island ports. On the Island of Kauai, Nawiliwili Harbor is the principal port. In 1987, about 916,000 tons of cargo, or about 6 percent of the tonnage through the system, was processed through Nawiliwili. We are currently in the midst of expanding the container yard and designing a new 800-foot pier and 8-acre storage yard.

On the Island of Maui, the container yard at Kahului Harbor is about to be expanded with the paving of an additional 3 acres. For the future, we are planning substantial increases in yard area and pier length to meet the forecasted cargo demand. In 1987, Kahului processed about 2 million tons of cargo or about 13 percent of the tonnage through the system.

The Island of Hawaii has Hilo Harbor on the east side and Kawaihae Harbor on the west. In 1987, Hilo Harbor processed about 1.4 million tons of cargo, or about 9 percent of the tonnage through the system. We will be expanding the container yard and are working with the Corps of Engineers in deepening the channel and basin. Future improvements include additional yard areas and pier length.

Kawaihae Harbor, Island of Hawaii, is experiencing the highest growth rate in cargo handling because of the current economic growth of West Hawaii. Construction of numerous visitor destinations has accelerated the volume of cargo flowing through the port. In 1987, the port processed about 871,000 tons of cargo, an increase of

32 percent over the 1986 volume. To meet this demand, we will be constructing a new storage yard and extending the pier by 600 feet.

The Governor's Office of State Planning recently completed a Honolulu Waterfront master plan. The plan envisions: (a) a major development of the Piers 8-11 complex, the design to be selected from proposals submitted by private developers; (b) Piers 1 and 2 container yards be converted into a cruise terminal with the present storage area converted to a people-oriented facility; and (c) about 67 acres to be purchased from the US Army to relocate the maritime activities from Piers 1 and 2.

Our system of commercial harbors needs constant improvements to meet the needs of our ever increasing resident and tourist population. As an island state, efficient and effective harbors are necessary for our sustenance and economic well-being.

BARBERS POINT DEEP-DRAFT HARBOR, OAHU, HAWAII

LTC Donald T. Wynn
Commander and District Engineer
US Army Engineer District, Honolulu
Honolulu, Hawaii

The POD is unique in that our area of responsibility within the Pacific Basin is totally composed of islands dispersed over an ocean environment exceeding 5 million square miles. The POD is responsible for administering Federal Water Resources Development programs in Hawaii, Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands.

The Honolulu District was established in 1905, when Congress authorized Hawaii's first civil works project--Improvements to Honolulu Harbor. Since that time, our civil works program has grown to include countless studies and projects aimed at enhancing water resources, not only in Hawaii, but throughout the Pacific Basin. Within recent years, the commerce and economy of the Pacific Basin community have become of increasing world importance. Today, there is more trade transacted among the nations of the Pacific Basin than in any other area of the world. With the emergence of the Pacific Basin as the world's most dynamic economic arena, Hawaii and its ports become even more important to the efficient movement of the area's trade.

Hawaii is the crossroad of the Pacific and straddles the time zones between Asia and the US mainland. Our working day overlaps the working days in Asia and the mainland. Hawaii's central location means its ports provide an excellent opportunity for transshipping, warehousing, processing, and marketing cargo in the Pacific trades. The geographic isolation of Pacific Islands has made the construction of commercial harbors a vital economic necessity. Since more than 90 percent of goods entering and leaving the 50th State is dependent on surface transportation, the Corps' civil works activities related to harbor improvements are significant contributions to the state's economy and well-being.

Barbers Point Harbor is located on Oahu's west coast approximately 16 miles west of downtown Honolulu. The location of the harbor is consistent with local government policy to shift much of the future urban and industrial activities towards the Ewa and leeward areas of the island. Facilities for surface transportation of goods entering and leaving the 50th State have become extremely limited due to the growth of metropolitan Honolulu towards the harbor over the years and requirements for various land uses on Sand Island.

Since gaining statehood in 1959, Hawaii's foreign trade has grown by some 4,000 percent from a total of just over $52 million to over $2 billion today. The

development of two major oil refineries at Campbell Industrial Park near Barbers Point on West Oahu significantly impacted Hawaii's international trade pattern. Today, more than half of the state's international trade focuses on petroleum products. In 1986, there were over 4,300 ship movements through the Hawaiian ports. Of these, 1,968 were overseas voyages between Hawaiian ports and ports on the North American continent.

The Barbers Point project was authorized by the R&H Act of 1965. In 1968, the Corps conducted design and model-testing studies. In 1969, the State Legislature appropriated $200,000 for the project. This was followed in 1971 by an additional $4 million appropriation. During the 1970 decade, harbor development design including a hydraulic model study, resulted in a land-locked harbor plan without any offshore breakwaters. Mitigation measures to compensate for impacts to an endangered species, *E. skottsbergii*, were undertaken. Cultural resources were salvaged. Harbor circulation and flushing predictions based on significant groundwater leakage into the harbor were completed. Construction of the first phase of the total harbor development was initiated following award of a $47 million contract in March 1982, for work on general navigation facilities. The first phase of the project was dedicated in August 1985.

The project consists of:

a. Offshore entrance channel 4,200 feet long, 450 feet wide, and 38 to 42 feet deep.

b. Inshore harbor basin of 92 acres and 38 feet deep.

c. Wave absorber structures of 4,600 linear feet.

The second phase of the harbor was dedicated in December 1986. The State has scheduled to incrementally develop the necessary shoreside facilities spending $12.1 million over the next two decades to complete the harbor project. Since 1986, the Barbers Point project has been monitored under the MCCP program. Under this program, a series of wave gages have been installed to monitor the effectiveness of the prototype to the design predictions for short-period as well as long-period oscillation. The gaging will continue until April 1990.

The harbor is designed to meet many different desires of the general public. The primary benefit to the general public will be from transportation savings for goods destined to leeward Oahu.

Total cost of the project to date is $63,600,500 (Federal: $55,300,500; non-Federal: $8,300,000).

LOS ANGELES/LONG BEACH HARBORS

Dwayne G. Lee
Deputy Executive Director, Development
Port of Los Angeles

The Ports of Los Angeles and Long Beach are two separate entities, two different jurisdictional activities that work for two different cities, and they are competitors. However, in a number of areas they have historically agreed on cooperation. It makes sense to pool resources to work on problems that are common to both ports. That has been the case with the 2020 plan. It is a plan that has been developed with the support, participation, and consensus of both ports.

The two ports together are the number one port in the United States, in terms of tonnage, in terms of dollars, and in terms of value of cargo and customs revenue raised. In most of the categories that count, the combined port is fourth in the world.

The 2020 plan is the infrastructure projection out to the year 2020, of what is critical, in the judgment of the ports, to continue to sustain the level of service that they are now providing to the country both domestically and internationally. The projected investment for the two ports is $5 billion. The Federal dredging project, which is the necessary and important step to get started, has a cost estimate in the range of $340 million. The Federal share of that would be about 30 percent, or the Federal investment would be about $100 million compared with a port's investment of $5 billion.

LA/LB 2020 PLAN

John W. Warwar
Port of Los Angeles
and
Dr. Geraldine Knatz
Port of Long Beach

This joint presentation will address the history, planning, and engineering of the master plan for the development of the San Pedro Bay Ports, which is known as the 2020 Plan. In November 1985, the Ports of Los Angeles and Long Beach approved a master plan known as the 2020 Plan. The plan was prepared by the Los Angeles District of the Corps and the Ports of Long Beach and Los Angeles in response to a resolution adopted by the US Congress in 1968. The purpose of the plan is to provide the necessary deepwater channels, new land, marine terminal facilities, and related transportation infrastructure needed by the year 2020. Since plan approval, the Ports of Los Angeles and Long Beach have undertaken an extensive program to refine planning, engineering studies, and environmental parameters of the plan. A portion of the plan, the Pier J expansion in Long Beach, is already under construction, and the 190-acre reclaimed land from the recent Los Angeles channel deepening is being consolidated for the Pier 300 development.

The ports contracted with Wharton Econometric Forecasting Associates to refine cargo forecasts. With the updated cargo forecasts as a base, an Operations, Facilities, and Infrastructure Study (OPI) was undertaken to quantify enhancements possible at existing port terminals and to determine acreage and capacity requirements for new terminals. As part of the OPI study and related transportation studies, a program of highway and rail improvements was incorporated into the plan.

Implementation of the plan will occur in two phases and result in an expanded port complex of 2,400 acres of new land and 600 acres of redevelopment on existing lands resulting in 38 new maritime terminals. Because the plan is massive in scope, environmental concerns are paramount. In January 1988, an interagency task force called the Biomitigation team was established to develop and implement mitigation projects to offset impacts on the marine environment for Phase I of the plan. Critical to the acceptance of the plan by environmental agencies is the assurance that water quality in existing channels will remain at acceptable levels. The numerical model at WES was upgraded to three-dimensions with the inclusion of water quality parameters. Preliminary results indicate that although circulatory patterns may be altered, no significant water quality problems will result from the configuration of the new landfills.

The 2020 Plan is a continuation of a process which started over a century ago and resulted in the development of the San Pedro Bay harbor complex into one of the

finest and largest in the world. A major event in the San Pedro harbor development was when the Corps of Engineers started construction in 1899 on 8,500 feet of the San Pedro breakwater, which was completed in 1911, and the channel was dredged to 18 feet. The 2020 Plan is yet another giant step in the further development of this harbor complex to meet the regional and national needs.

When fully implemented, the 2020 Plan will result in the creation of deepwater channels with depths varying from 50 to 84 feet, resulting from 225 million cubic yards of dredging. These channel depths and widths were based on a fleet forecast study up to the year 2020, which analyzed the type and sizes of vessels and their drafts. The study developed projections by type, number, and size of vessels which will serve the Los Angeles and Long Beach Ports complex, taking into account the cargo projections and trade routes.

A number of major planning and engineering criteria were critical parameters in the formulation and shaping of the plan. They included water channel configurations to accommodate projected fleet, protection of berths from surge and short-period waves, provision for water circulation to maintain or enhance water quality, allocating and locating terminals based on highest and best use, optimizing rail and road access to terminals, and cost effectiveness and phasing flexibility.

The 2020 Plan has undergone and continues to undergo extension and rigorous engineering tests and refinements. In addition to numerical water circulation and water quality modeling at WES, numerical modeling of surge, coupled with field measurements at both ports, was also conducted by WES to assess ship motion. In addition, the LA/LB long-period wave hydraulic physical model has been upgraded and is ready to test the plan. An undistorted 1:100 scale hydraulic model was constructed at WES and tested the Los Angeles portion of the 2020 Plan for short-period wave attack. The Port of Los Angeles further conducted a navigation simulation study at the Marine Safety International/Computer Aided Operations Research Facility to examine the planned channels and turning basins. A comprehensive geophysical and geotechnical program is underway by the Port of Los Angeles. The geotechnical program will provide essential design and construction information relating to the dredging of the 85-foot deep channels and creation of landfills. The geophysical program will investigate the Palos Verdes Fault relative to the Los Angeles landfills. A seismic workshop and symposium is planned by the Port of Los Angeles to address these issues, which will include world renowned experts in these fields. The design and construction of the 2020 Plan will also rely very heavily on the experiences gained from the Pier J design and construction, as well as the recent Los Angeles harbor deepening project and the ongoing consolidation of the 190-acre landfill.

The 2020 Plan is estimated to cost over $5.0 billion in today's dollars when fully implemented, of which $1.6 billion is for dredging and landfills. The projected economic benefits of the plan to the region and the Nation as a whole almost dwarfs this estimated cost.

LA/LB 2020 PLAN--FEDERAL REQUIREMENTS

Alan E. Alcorn
US Army Engineer District, Los Angeles
Los Angeles, California

The Corps of Engineers' feasibility study is for Los Angeles/Long Beach Harbors formulated to integrate the ports' future needs with Federal interest, primarily to look at ways to decrease National transportation costs. This focus has been precipitated by the growth in commodity and fleet projects referred to in earlier presentations by Mr. Warwar and Dr. Knatz. The growth rates, and the facilities required, indicate the types of problems that will develop in the future.

The Los Angeles District is reviewing the commodities, their origins and destinations, the existing ports, and the fleet forecast as part of the present formulation. The problems being investigated center around inadequate navigation channel depths as well as capacity of terminals. The Corps' feasibility study is focusing on three major cargo groups: liquid-bulk cargo, dry-bulk cargo, and containers. The majority of the benefits that will come from navigation improvements are for those three cargo groups.

The Corps is looking individually at channels, facilities, and commodities to establish cost savings. Proposed construction has been broken into stages to meet the needs as they occur. The first stage is needed immediately. That consists of two increments. The first increment would be a channel through the Long Beach entrance up to Berth 121 to handle vessels up to 300,000 deadweight tons. The second increment would be a channel through the Port of Los Angeles to the dry-bulk facility to handle vessels up to 250,000 deadweight tons. The dredged material from the first increment would be used as fill to create Piers J and K on the Long Beach side, and the material from the second increment would be used to create Pier 400.

The second stage, or increment 3, would be needed around 1997. That would deepen an existing channel and add a spur channel. The third stage would be increments 4, 5, and 6 and would be needed around the year 2005. Increment 4 would be for a container terminal in the Port of Los Angeles at Pier 300, and the dredged material would be used for additional fill at Pier 400. Increment 5 is also a container terminal, and that material also would be used for fill at Pier 400. Increment 6 would be a channel and turning basin to serve Pier K in the Port of Long Beach.

The Federal project is somewhat different from the total 2020 plan presented by the ports. The feasibility study for the Federal project looks at navigation improvements and does not include portions of the 2020 plan which were fill only.

The feasibility study is scheduled to have a draft document ready for review in early 1990, and will be ready for Washington-level review in the spring of 1991.

DISCUSSION

LTC Wynn asked about the effect on the infrastructure of the surrounding community. Dr. Knatz said they are developing a consolidated transportation corridor to provide an additional route between the harbors and Los Angeles which will alleviate problems on existing freeways. They are also seeking funding for an extra lane on the Long Beach Freeway. In the Environmental Impact Report-Environmental Impact Statement that is under preparation, there is an examination of the social impacts.

Mr. Boe asked about mitigation for loss of wetlands and the ratio used for required replacement. Dr. Knatz indicated that the ratio is determined for each specific site. It depends on existing habitat values at the site. On the Anaheim Bay project, the ratio was 1.32 to 1; i.e., they could fill 1.32 acres for each acre of marsh created. Other sites have different ratios. If there is an existing habitat value, that gets subtracted when the marsh is created or upgraded.

LA/LB HARBORS MODEL ENHANCEMENT PROGRAM

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US Army Engineer Waterways Experiment Station

Summary

In response to the expansion of oceanborne world commerce, the Ports of Los Angeles and Long Beach, California, in coordination with the Los Angeles District of the US Army Corps of Engineers, are conducting planning studies for harbor development to accommodate future needs. The Corps is charged with responsibility for providing deeper navigation channels and determining effects of the harbor expansion on the environment, while both ports plan construction of new landfills, basins, and berthing facilities. The Los Angeles/Long Beach Harbors Model Enhancement Program has been developed to significantly upgrade the Corps' capability to determine effects of this expansion based on state-of-the-art modeling technology. Major elements of the Model Enhancement Program include tidal circulation and water quality (including wind effects), harbor resonance, and ship motion. The results of the Model Enhancement Program will provide a vastly improved capability to evaluate the effect of harbor improvement plans on these parameters, thereby ensuring the optimal harbor development.

Historic Background

In 1970, WES was funded to conduct a comprehensive hydraulic model study of Los Angeles/Long Beach Harbors to investigate the effects of proposed harbor expansions on tidal circulation and long-period wave oscillations. The major objectives of this study were:

a. Determine incidence and severity of troublesome oscillations in the present harbor complex.

b. Investigate tidal circulation characteristics of the present and proposed harbors.

c. Determine the optimum plan for future expansions to provide safe and economical berthing areas.

d. Analyze effects of proposed expansions on existing harbors.

The WES approach to achieve these objectives was:

a. Acquire prototype wave data for a 1-year period.

b. Obtain observations of ship motion.

c. Catalog ships using the harbors.

d. Conduct analytical investigations of moored-ship response.

e. Perform extensive analyses of prototype wave data.

f. Attempt to correlate ship motion with wave height and frequency.

g. Collect prototype data for model verification of tidal circulation characteristics.

h. Design and construct a hydraulic model.

i. Conduct model tests of tidal circulation for present harbors and planned construction stages.

j. Conduct model tests of long-period wave characteristics of existing harbors and planned construction stages.

In designing the hydraulic model, the effects of wave refraction, diffraction, reflection, and transmission; viscous friction attenuation; wave filters and absorbers; wave generator requirements; automated model data acquisition and control; and model data analyses were considered. The model was constructed to a vertical scale of 1:100 and a horizontal scale of 1:400 (for a distortion factor of 4) and reproduced approximately 253 square miles of prototype area. Model construction was completed in August 1973. Initial testing was aimed at evaluating various phases of harbor expansion (leading up to a master plan development) to optimize modifications from a cost and functional standpoint.

During the initial years of model testing, it became apparent that the model was evolving as a planning tool for use by both the ports and the Corps and that its usefulness would span decades as changing customer needs and environmental concerns surfaced. With this redefined role came the realization that periodic upgrades in the LA/LB model technology would be necessary to maintain state-of-the-art research studies.

By the early 1980's, rapid advances in coastal engineering, particularly in numerical model development and the advent of large and powerful computers, made the 1970's technology (with which the hydraulic model of Los Angeles/Long Beach Harbors had been designed and operated) outdated. Therefore, a long-term tidal circulation, harbor resonance, and ship motion study was initiated in FY82 to obtain data for improving evaluations of the harbor's response to forcing functions such as the astronomical tide, wind, and long-period waves. These data then would be applied to further upgrade model capacity to predict the effect of proposed expansion plans on tidal circulation, water quality, and harbor oscillation. The program was funded at sporadic levels (partial or no funding) from FY83 to FY86. In FY87, the upgrade program finally received full support with approval of a 5-year (FY87-FY91), $4 million program.

Due to the large scope and complexity of the work to be performed, a structured management plan was developed with well-defined roles for the following parties:

Los Angeles District (SPL)	Waterways Experiment Station (WES)
South Pacific Division (SPD)	Port of Los Angeles (POLA)
HQUSACE	Port of Long Beach (POLB)

Work for the Model Enhancement Program is being conducted by two of WES' six laboratories: CERC and the Environmental Laboratory.

Outline of the Model Enhancement Program

The Model Enhancement Program has been separated into two major studies. The first is connected with the action of long-period waves (periods of 25 seconds and longer) on the harbors. Very little is known about the origin and frequency of occurrence of these waves, but their existence is evident in producing difficult loading/unloading events at various berths throughout the harbors. This portion of the Enhancement Program will provide prototype wave data, a moored-ship motion model, and an upgraded testing capability (spectral waves) for the physical model. An introductory outline of this phase of the study is as follows:

a. Develop long-wave frequency of occurrence from wave spectra data collected at prototype wave gages in the harbors and the Pacific Ocean.

b. Correlate moored-ship motion with incident wave spectra by monitoring prototype ship movements.

c. Verify a moored-ship model.

d. Establish frequency of occurrence for loading/unloading downtime (as a function of berth location, mooring configuration, and ship characteristics).

e. Provide improved modeling methodology for evaluating the effects of SPL and the ports' improvement plans and dredging on loading/unloading downtime.

The second major part of the Model Enhancement Program will provide improved tidal circulation modeling with a more efficient numerical tidal circulation model system which will couple hydraulics and water quality variables. This is outlined as follows:

a. Acquire prototype tidal data.

b. Quantify outer harbor and inner harbor circulation.

c. Evaluate and quantify water quality processes.

d. Evaluate and quantify the effects of wind on tidal circulation and mixing processes in the harbors.

e. Provide improved modeling methodology for evaluating the effect of proposed harbor improvements on circulation and water quality.

The basic sequence involved for each of the above two major divisions is to collect prototype data to improve model predictions and define important test conditions for the existing harbors and then apply the models (physical harbor resonance model, numerical ship motion model, and numerical tidal circulation and water quality model) to determine the effect of harbor development plans.

Model Enhancement Program Tasks

Specific tasks identified in the Model Enhancement Management Plan and their status are:

Task A.1	Wave Data Acquisition (in progress)
Task A.2	Wave Data Analysis (in progress)
Task A.3	Harbors Resonance Analysis (in progress)
Task A.4	Ship Motion Data Acquisition and Analysis (completed)
Task A.5	Ship Motion Model Development, Calibration, and Verification (in progress)
Task A.6	Improved Physical Model Harbor Resonance Methodology (completed)
Task B.1	Tidal Circulation Data Acquisition/Tidal Elevations (completed)
Task B.1	Tidal Circulation Data Acquisition/Currents (in situ) (completed)
Task B.1	Tidal Circulation Data Acquisition/Currents (profiles) (completed)
Task B.1	Tidal Circulation Data Acquisition/Currents (Lagrangian) (completed)
Task B.1	Tidal Circulation Data Acquisition/Data Analysis and Report (in progress)
Task B.1	Tidal Circulation Data Acquisition/Water Quality Sampling (completed)

Boundary Survey	Sediment Oxygen Demand Survey
Interior Surveys	Core Survey
Diel Survey	CBOD Rates
Productivity Survey	Dye Release Study

Task B.2	Circulation Transport Model (completed)
Task B.3	Water Quality Model (completed)
Task B.4	Wind-Driven Circulation Analysis (in progress)
Task C.1	Project Management (in progress)

(Discussion follows the presentation by Mr. David D. McGehee.)

FIELD MEASUREMENTS IN SUPPORT OF THE LA/LB HARBORS MODEL ENHANCEMENT PROGRAM

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The major elements of the Los Angeles and Long Beach Harbors Model Enhancement Program are tidal circulation and water quality, harbor resonance, and moored-ship motion models. Data were obtained from a tidal hydraulics study in the summer of 1987 and a ship motion study in the winter of 1989 to calibrate and verify the circulation and ship response models. This paper outlines the approach used in each and summarizes the results.

Tidal Hydraulics Study

The required products from this effort were a 90-day time series of water surface elevations at two locations outside the harbor and two locations inside, a 30-day time series of vertical velocity profiles at eight locations inside the harbor, and velocity distribution across all major harbor flow paths over one-half of a tidal cycle.

Tidal elevations were obtained from bottom-mounted pressure transducers in self-recording, microprocessor-controlled instruments. Elevations were reduced to mean lower low water by assuming a common average sea level over the 90-day record for all gages and adjusting for the monthly variance in mean sea level as measured from a National Ocean Service primary tidal station in Los Angeles Harbor.

Vertical velocity profiles were obtained with impeller-type, self-recording current meters attached at intervals to taut-moored buoys. The meters align with the current and use internal compasses for direction. Their 30-day deployment was nested in the 90-day interval of the tide data collection for concurrent measurements.

Velocity distributions were measured at eight transects on subsequent days using a similar type of meter, but with the data sent over an umbilical cable to a laptop computer. The meter was lowered periodically from a boat moored at intervals across the transect. Typically, five stations were selected across the transect, and each would be profiled hourly at four depths from peak flood, through slack to peak ebb conditions. In addition, four locations were profiled in the Cerritos Channel to identify nodal points between the entrances.

Comparison of the residual signal from pairs of tide gages--the instantaneous hydraulic head--and resulting currents between the gages shows good agreement in

amplitude and phase for all reported stations. A transient node was observed that migrated counterclockwise with the net circulation through the Cerritos Channel. A weak gyre can be detected in Los Angeles Harbor with significant vertical stratification. The general trend in the harbor complex during the course of the study is to fill from the western openings on the flood and drain to the east on ebb.

Ship Motion Study

The requirement for this task was to obtain four data sets from two separate bulk cargo ships at the Port of Los Angeles and two container ships at the Port of Long Beach. Each data set consisted of continuous, synchronized, 4-hour time series of vessel motion in all 6 degrees of freedom and reaction loads in up to eight mooring lines. Incident long-period wave energy was obtained from gages placed outside and inside the harbor under a separate task of the program.

The measurements were scheduled for February and March because records indicated they were the most energetic periods. Data collection had to occur during routine operations without delaying berthing or interfering with cargo transfer. Signal processing, analysis, and data display had to occur in near real-time to allow quality assessment prior to arrival of the next vessel. The entire system had to be transportable and operational within a few days of arriving onsite, and survive hazards such as container truck traffic, coal dust, and extreme electrical noise, in addition to the normal marine environment. An uninterruptable power supply was needed in the event of power loss in the port.

The system consisted of onboard and remote motion sensors for the vessel response, in-line tension load cells for the reactions in the mooring lines, with telemetry links to a control van containing separate signal processing and data analysis computers plus data storage units. Rotations were measured from tilt sensors (pitch and roll) and a gyrocompass (yaw) mounted on the deck of the ship. Translations (heave, surge, and sway) were measured with an auto-tracking total surveying station on the dock sighting a prism mounted on the ship. Two video cameras recorded the bow and stern to provide redundant surge and heave capability and to visually verify recorded data. Load cells were placed in the mooring lines when the ship docked. Armored cables carried the signals to dockside power/telemetry modules for transmission to the control van.

At the Kaiser Coal Terminal in Los Angeles, pneumatic fenders provided the opportunity to measure fender reactions as well, by installing pressure transducers at the air valves. Finally, an anemometer was included to record wind effects. In all, 18 channels of data were telemetered to the collection computer, synchronized, and

merged into a single file. The file was downloaded to the analysis computer hourly and converted to engineering units with the proper sensor calibration constants. Time series plots of each channel were available for viewing within minutes so that timely operational decisions could be made.

In addition to the automated data, a large quantity of information was collected for each vessel. Ship documents including plans, stability curves, load/displacement tables, etc., were obtained for most vessels. Mooring line material, size, condition, and layout from deck to bollard were noted and photographed. Draft was recorded periodically at the bow and stern, as were hull-to-fender separation. For the bulk cargo ships, a load histogram was constructed.

During the 6 weeks of field measurements, three bulk cargo ships at Los Angeles and two container ships at Long Beach were instrumented and successfully measured, producing a total of 41 hours of synchronized time series. This unique data set is the first to simultaneously record the incident-forcing wave and wind energy and the complete 6 degrees of freedom response of the vessel plus mooring line and fender reactions.

The conditions encountered were generally mild, particularly when compared with the 17 March storm of the previous year. Maximum translation (surge) was on the order of a foot and maximum roll on the order of 2 degrees. These conditions were sufficient, however, to significantly delay the loading of one of the container ships, causing it to spend an extra day in port. The study provided many valuable lessons and advanced the art of ship response modeling.

DISCUSSION

Prof. Raichlen said that the numerical model of a nonlinearly moored ship is pretty complicated. There are questions as to whether you have really modeled, hydrodynamically, certain aspects such as virtual mass. He was surprised that attention was not given to a physical model. The bottom line for the LA/LB program is really the effect on the ship itself. That could be used to verify the numerical model. He said he had observed a nonlinearly moored ship model test in The Netherlands, conducted specifically to look at this type of ship motion in one of the German ports. Mr. McGehee said he would be concerned about proper modeling of mooring line reaction because of material properties. Prof. Raichlen said there are approximate ways to model that. Mr. Chatham said the original intent was to use physical models, but with the advent of numerical models, the decision had been to go directly to numerical and to verify the numerical model with the prototype data.

Prof. Dalrymple asked how far along CERC was on the calibration. Mr. Chatham said CERC was in pretty good shape, but does not have all the prototype data yet. There was some delay getting data from the contractor taking the data, and CERC had projected a 3-month delay in the program to the District. CERC had hoped to use a data set from Iceland for verification, but that was not as successful as they had hoped.

LA/LB HARBORS MODEL ENHANCEMENT PROGRAM
Three-Dimensional Hydro-Environmental Model

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Introduction

Los Angeles and Long Beach Harbors are located adjacent to each other on the southern California coast and share a common breakwater system that encloses one of the largest harbor complexes in the world. The harbors' history since the turn of the century has largely been one of continuous expansion to meet demands of world commerce and national security. Additional facilities have been constructed using dredged material for landfill. Again, a dramatic increase in activity is predicted for the Pacific trade routes, and to meet these trade needs, the ports are undertaking a long-range cooperative planning effort (2020 Plan) to expand terminal and container transfer facilities. The purpose of this hydro-environmental study is to apply a 3-D hydrodynamic and water quality model to investigate tidal and wind-driven circulation, flushing, and water quality for existing conditions in the harbors and demonstrate use of this technology in estimating impacts of harbor enhancement plans on circulation and water quality.

Computational Models

Harbor enhancements may affect water quality in the harbor complex by changing tidal circulation and harbor flushing patterns that presently exist. A major concern is the potential impact on the dissolved oxygen (DO) resource. Channel deepening introduces the possibility of DO stratification where well-oxygenated surface waters overlie oxygen-depressed bottom waters. To investigate this problem, a 3-D hydrodynamic (CH3D) and water quality Integrated Method (ICM) model system was selected. Model CH3D is a time-varying 3-D hydrodynamic model for simulating circulation affected by tide, wind, river inflow, and density currents induced by salinity and/or temperature gradients. The basic equations include the equations for continuity, conservation of momentum, salinity/temperature transport, and an equation of state. The model accepts a generalized coordinate grid to approximate the horizontal domain and uses a vertical-stretching relationship to obtain a smooth representation of the bathymetry with equivalent resolution in both shallow and deep regions of the study area. To facilitate a more efficient numerical scheme, an external/internal

mode-splitting technique is used. A theta-weighted implicit finite difference approach is taken to solve for the surface elevation, three velocity components, salinity, and temperature.

The water quality model ICM is a modification of the EPA WASP code. Major adaptations include improved advective and diffusive transport schemes (for both horizontal and vertical transport), provisions for interfacing with a hydrodynamic model, and the implementation of kinetic routines specific to this application. The hydrodynamic and water quality models were linked by spatially and temporally averaging CH3D output to drive the ICM model.

Grid Selection

A successful and accurate grid was used in a previous hydrodynamic model study of San Pedro Bay. The study area was represented by a smoothly varying rectilinear grid containing 12,032 grid cells (Figure 1) with the grid aligned to coincide with the inner harbor entrance channels. The minimum cell width in the grid is 72 meters (235 feet); a computational time-step of 60 seconds was necessary to obtain accurate results. In contrast, the ICM model has characteristic time scales on the order of hours, which are determined by the kinetic rate coefficients. Consequently, the desired analysis of water quality allows a spatial resolution an order of magnitude less than that used by CH3D and a time-step of 15 minutes. The ICM grid is also shown in Figure 1. Both models used three layers in the vertical.

Model Testing, Calibration, and Verification

Prior to model calibration, several sensitivity tests were conducted with the hydrodynamic model. These included runs with tidal constituent forcing, pure wind-driven forcing, measured tidal forcing with and without wind, and use of varying number of layers in the vertical. These tests also included investigation of the influence of model coefficients such as bottom friction, horizontal and vertical eddy viscosities, and wind drag. The primary tests conducted with the ICM model were to validate linkage with CH3D and to ensure that transport properties of CH3D were maintained with the interfacing. These tests were conducted with calibrated CH3D results.

Data during the month of August 1987 were acquired specifically for the purpose of calibrating and verifying the hydrodynamic and water quality model system. The period from 7-11 August was taken as the calibration period for CH3D. Several simulations were made varying eddy coefficients and bottom friction to calibrate to

measured current speeds and directions throughout the water column. The final set of model coefficients chosen were Manning's n = 0.02 and horizontal and vertical eddy viscosity coefficients of 20,000 and 10 square centimeters per second, respectively. A second simulation (19-23 August) was made without adjusting model coefficients to assess the quality of comparison of the model to an independent set of observed data. A quantitative measure of goodness of fit was not attempted due to the frequency of subtidal oscillations in the harbor. To match each and every 1-hour subtidal oscillation would require commensurate accuracy in measured forcing data (wind and the boundary ocean tide both spatially and temporally) and geometry representation.

As expected, excellent agreement between model and measured results was obtained for surface elevations. For currents, the overall quality of the match between model and measured data indicated the model was reproducing current behavior throughout the harbor complex. The model did reproduce subtidal oscillations, and the amplitude of these oscillations was consistent with that observed in the prototype. The model result did exhibit a net circulation to the west in Cerritos Channel as found in previous physical and numerical model studies.

Tracer tests were used to guarantee the ICM model was preserving transport properties of CH3D. Tracer injections were made to several hydrodynamic grid cells in the surface layer. These cells corresponded to a single ICM cell. The behavior of the tracer was simulated over several days in both models, and the decline in tracer concentration was in excellent agreement. A concern that capturing the subtidal oscillation feature in the hydrodynamic results may be important in the ICM model was checked by another tracer test. Tracer injections were simulated with both a 15- and 60-minute average of CH3D results. Decline of tracer concentrations was the same in both simulations, which confirms that a 60-minute average is sufficiently accurate for ICM use. The ICM model was calibrated against observed data obtained during the August 1987 period. The model simulates DO, carbonaceous biochemical oxygen demand (CBOD), ammonia nitrogen (NH_4-N), nitrite plus nitrate nitrogen (NO_2+ NO_3-N), algal biomass as carbon, orthophosphate (PO_4-P), and a conservative tracer. Temperature and salinity were held constant. Initial conditions were specified by assuming horizontally constant yet vertically stratified water quality based on observed measurements. The observed data show the harbor system is nitrogen limited, with little water column respiration, and not productive in terms of algae. Therefore, the most important concerns were benthic respiration or sediment oxygen demand and water residence time or flushing characteristics. CH3D was used to simulate hydrodynamics for the entire month of August, and time-averaged results were used by the ICM model. Measured and ICM model water quality results are in good agreement throughout the harbor.

Demonstration of Plan Impact

The plan used to demonstrate model analysis of hydrodynamic and water quality impact was a proposed facilities expansion and channel-deepening project referred to as Scheme B. Bathymetric and topographic changes reflecting the plan were introduced into the model grid, and CH3D was run for the month of August. The calibration and verification periods during the month were examined separately to study the impact on hydrodynamics. Basic impacts included reduction in harbor entrance velocities and tidal prism corresponding to channel deepening and reduced tidal storage area occupied by the project landfill. With expansion facilities in the outer harbor, transport across the outer harbor is confined to a new channel adjacent to the outer breakwater, and the gyre circulation in the outer harbor is prohibited. Net circulation in Cerritos Channel has a tendency to reverse to a clockwise direction, i.e., from west to east.

Flushing studies were used to provide a qualitative comparison between plan and existing conditions. A decrease in the flushing rate prolongs the period of time that oxygen-demanding substances exert their influence on DO concentration and may indicate a potential water quality problem. The initial test involved injecting a tracer throughout the harbor inside the outer breakwater and simulating its behavior over a 25-day period. Any tracer leaving the harbor is assumed lost so the decline of tracer concentration gives an indication of the flushing characteristics of the harbor. This run indicated three areas with potential problems: East Basin, Seaplane Anchorage, and Navy Harbor. Separate tests were made by injecting a tracer in a confined area of each potential problem basin. These tests indicated some small reduction in flushing would occur with the plan but would not be significant enough to impact the existing good water quality of the harbor. The tracer tests confirm the change in net circulation to a clockwise direction with the plan in place. These tests also provided information on where to examine impacts in the water quality simulations.

Again, the CH3D plan simulation results for the month of August were used to complete the water quality simulation for plan impact. All results revealed that DO concentrations at all stations were essentially equivalent between existing and plan conditions. Bottom waters exhibited lower DO relative to surface waters, but concentrations were greater than 5 milligrams per litre at all stations. The conclusion of these water quality simulations was that DO resources of the entire harbor complex were not adversely affected with the introduction of the Scheme B plan, even with reduced flushing in some harbor areas.

Additional studies have been conducted for the ports to evaluate three additional plans for the 2020 concept. Results for all plans were similar to those obtained for Scheme B. The basic conclusion from these simulations is that the existing water

quality of the harbor complex is good and the implementation of any 2020 plan tested in these studies would not significantly alter the harbor's water quality.

The reader is referred to technical reports on the studies discussed previously, published by WES, for additional information and references to other studies.

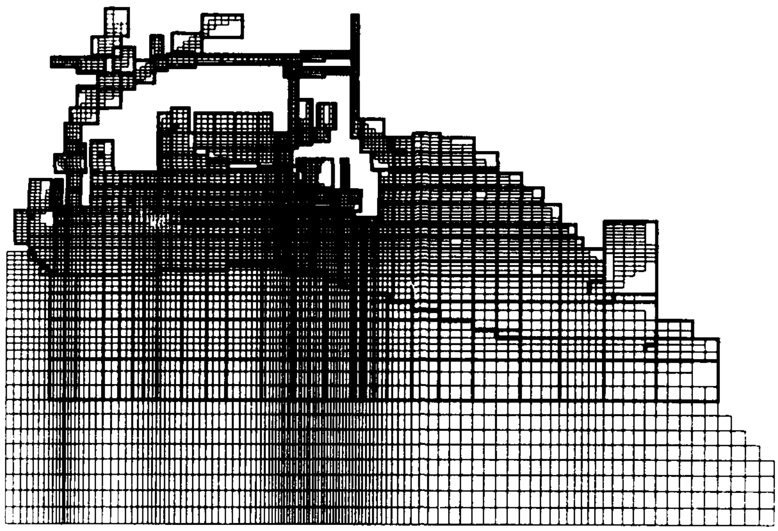

Figure 1. Overlay of water quality grid on hydrodynamic grid

DISCUSSION

Prof. Dalrymple asked what measures were used to decide whether or not to accept the model results in the calibration procedure. Mr. Butler said that was a tough question. Normally CERC would use some sort of statistical measure. In this case, the degree of oscillation in the data made it very difficult to make such a comparison. The quality of the comparison would vary between gages. To make the comparison, we need to accurately establish the data along the open boundary which would require more gages and expense. We would need a significant number of gages to establish the spatial variation in wind. CERC believes the data are good, but to come up with a quantitative comparison, we need better forcing data and geometric representation of the system. These results express a qualitative fit.

Prof. Dalrymple said he could understand the hourly surge phenomenon, but there are ways to discriminate which might shed some light on whether you have problems with the data. Mr. Butler said they did actually run the model with tidal constituent forcing on the outside. Using tidal constituents, you eliminate the oscillation. You can also average the data that were measured. CERC made those comparisons, and they were quite good.

Prof. Reid asked if there was much salinity stratification. Mr. Butler said there was not, but that the data were for the month of August. There may be times when there is stratification, but generally, the harbor is a pretty homogeneous system. You do see a different circulation from top to bottom. Prof. Raichlen asked if they had looked at the possible effects of freshwater discharges from the Los Angeles River. Mr. Butler said such discharges are episodic events, and they had not been looked at.

Prof. Reid asked about future plans. Mr. Butler said the results they had were for Phase I of the 2020 Plan. As the ports proceed with other phases of the plan, CERC will probably do additional testing.

UPDATE ON DREDGING RESEARCH PROGRAM TECHNICAL AREA 1 "ANALYSIS OF DREDGED MATERIAL DISPOSED IN OPEN WATER"

Dr. Nicholas C. Kraus
Technical Manager, Technical Area 1
Research Division
and
E. Clark McNair, Jr.
Program Manager, Dredging Research Program
Coastal Engineering Research Center
US Army Engineer Waterways Experiment Station

Overview of the Dredging Research Program

The Dredging Research Program (DRP) was launched in January 1988 and is a 7-year research and development program aimed to address problems and needs of the Corps in its dredging mission. The DRP is organized into five functional or technical areas: (a) Analysis of Dredged Material Disposed in Open Waters; (b) Material Properties Related to Navigation and Dredging; (c) Dredge Plant Equipment and System Processes; (d) Vessel Positioning, Survey Controls, and Dredge Monitoring Systems, and (e) Management of Dredging Projects. Each technical area is headed by a Technical Area Manager, who reports to the DRP Program Manager. Technical areas contain from four to seven DRP research work units, each work unit headed by a Principal Investigator (PI) who reports both through his or her normal chain of command and to the associated Technical Area Manager and DRP Program Manager. Principal Investigators and Technical Managers were drawn from the six laboratories at WES and from the Engineer Topographic Laboratory. Corps Districts also play a major role in performing work under the DRP and providing review of the total program.

Structure of Technical Area 1

Technical Area 1 consists of seven highly interconnected work units that range in purpose from theoretical improvements of boundary layer physics (eddy viscosity, shear stress, entrainment, and transport) through numerical calculation of dredged material movement and instrumentation for research-level measurement of fluid and dredged material transport properties through guidance on monitoring instrumentation and procedures.

Work unit titles and PIs are:

a. Calculation of **Boundary Layer Properties** (Noncohesive Sediments), Dr. Nicholas C. Kraus, CERC, WES.

b. Calculation of **Boundary Layer Properties** (Cohesive Sediments), Mr. Allen M. Teeter, Hydraulics Laboratory (HL), WES.

c. Measurement of **Entrainment and Transport** (Noncohesive Sediments), Dr. Nicholas C. Kraus, CERC, WES.

d. Measurement of **Entrainment and Transport** (Cohesive Sediments), Mr. Allen M. Teeter, HL, WES.

e. Numerical Simulation Techniques for Evaluating the **Short-Term Fate and Stability** of Dredged Material Disposed in Open Water, Dr. Billy H. Johnson, HL, WES.

f. Numerical Simulation Techniques for Evaluating the **Long-Term Fate and Stability** of Dredged Material Disposed in Open Water, Dr. Norman W. Scheffner, CERC, WES.

g. **Field Techniques and Data Analysis** to Assess the Fate of Open-Water Disposal Deposits, Mr. Edward B. Hands, CERC, WES.

In addition to conducting theoretical, numerical, laboratory, and field investigations in house, the problem area has initiated contracts with universities, other Government agencies, and private business. Example organizations are (a) universities: Massachusetts Institute of Technology, Ohio State University, Oregon State University, North Carolina State University, Texas A&M University, and the University of Florida; (b) Government agency: NOAA (Atlantic Oceanographic and Meteorological Laboratory); (c) large business: Evans-Hamilton, Inc.; and (d) small business: L. E. Borgman, Inc. Corps District offices at Mobile and San Francisco are also actively participating in technical area activities, and technical area PIs are increasing participation with other District offices.

In development of the structure of the problem area prior to the inception of the DRP, the seven work units were planned and established as an interconnected and integrated group to (a) provide Corps' field offices with predictive capabilities and guidance for estimating and measuring the movement of dredged material and to (b) exchange needed data and calculational results internally between work units of the problem area. The presentation will describe the relation between the work units in more detail.

Selected Accomplishments

Fiscal year 1989 was the first full year of funding for the DRP. Considerable progress was made in Technical Area 1, and, to provide coherency in the limited time available for our talk, the presentation will mainly focus on coordinated activities

associated with the recently completed Mobile, Alabama, Dredging Research Program Field Data Collection Project (MFDCP), which was conducted over 18 August-2 September 1989, at two dredged material placement areas outside Mobile Bay in the Gulf of Mexico. This data collection project, a scheduled milestone in several of the technical area work units, was enhanced to include emphasis on monitoring of dredged material disposal plumes, as instructed by BG(P) Kelly at a special 1-day review of the DRP by the Coastal Engineering Research Board held in Washington, DC, in February 1989.

Data collection for the MFDCP mainly took place aboard the 105-foot-long *R/V Pelican*, a research vessel contracted from the Louisiana Universities Marine Consortium. An experienced and intrepid 12-person scientific and engineering team consisting of coastal engineers, oceanographers, technicians, and support personnel remained aboard the *Pelican* for the 12-day cruise. This main data collection team was augmented by personnel based onshore who assisted with vessel positioning, sample taking from the barges, diving from the *Pelican* to deploy and recover instruments, and placement of additional instrumentation.

Field data collection is prone to uncontrollable fatal problems, including bad weather; mechanical, electrical, and electronic malfunctions; fatigue of personnel; and accidents. Incredibly, none of these demons dared to appear, and the MFDCP collected approximately double the potential amount of data estimated in the original schedule. Also, the Great Lakes Dredge and Dock Company, contractor at the site, was most cooperative in positioning of the dredged material placement operations. In all, 18 dredged material placements were monitored at 27- and 41-foot depths. Plume monitoring was accomplished by two different acoustic sensor instrument suites which measured sediment backscatter intensity and water current through the water column. Our Acoustic Resuspension Measurement System (ARMS) also functioned for 55 hours of data collection of boundary layer entrainment and transport measurements. Modeling work units will use the collected data to test and refine capabilities for predicting the short- and long-term fate of dredged material.

DISCUSSION

Prof. Reid said it was a very impressive program and the Board looked forward to seeing results, particularly of the measurement system. Prof. Raichlen said he also found it to be a very interesting program. He said in looking at the laboratory experiments, the thing that immediately came to mind was the diffusion and dispersion of treated sewage effluent. All you were doing was inverting it, but it was still a density plume problem. A great deal of work has been done in that area, both in terms of entrainment and the density current. He suggested reviewing the literature on sewage outfalls and also suggested using saline water released into fresh water to look at entrainment.

Prof. Raichlen asked, given a certain size distribution of the sediment, whether CERC had any calibration of the acoustic meters in terms of concentration. Dr. Kraus said the acoustic meters had been used since 1972 and no one has had a serious program to look at the backscatter and its proportionality with concentration. One way to approach the problem is to use several acoustic frequencies and get the relative backscatter. CERC has assembled a team from Ohio State University, RD Instruments, and NOAA; and they will be meeting to determine how to proceed. At the present time, there is no funding available. Prof. Raichlen suggested including someone from the University of Iowa because they have done a lot of looking at sediment concentrations.

PUBLIC COMMENT

Mr. Thomas P. Pratte added some additional comments from the Surfrider Foundation (see Appendix D). He said they would like to encourage the Corps of Engineers to place clean sand from dredging projects in offshore sandbars or on the beach as beach nourishment. Their primary concern is looking at recreational impacts. Traditional beach fills create an over-steepened foreshore area, not in equilibrium with the wave climate, and recreation conditions for surfers deteriorate immediately. They feel the placement of offshore bars is more in equilibrium with the wave climate and can provide temporary recreational enhancements as part of the project.

Mr. Pratte noted that dredging needs to consider grunion spawning seasons, and least tern nesting and feeding. Placement of material in offshore berms could be less harmful than building out beach foreshores, especially with regard to grunion. If more research was done in this area, we might find that we can open up the dredging windows. That would have implications in reducing costs of dredging projects.

The Surfrider Foundation is also interested in wave transformation over submerged, three-dimensional shoals. He feels the submerged shoals could provide beach protection and a substantial benefit to the public. He is interested in large-scale stability studies to see if such submerged shoal structures would remain in place during episodic storm events and an analysis of breaking wave characteristics over these types of structures. We are interested from a recreational standpoint, but it could be looked at in ongoing research on breaking waves.

We are looking at the sand placement at Bataquitos Lagoon in Carlsbad, California. This is 4 million cubic yards of beach nourishment. We are trying to encourage the city to look into the placement of an offshore berm as part of that. He thinks the Corps could provide some help in that regard. We are also looking at the Santa Ana River flood-control project. A substantial amount of sand will be coming from upstream, and they would be interested in investigating whether some offshore berms could be placed as part of that project.

In regard to structures, Mr. Pratte said they were presently looking at Surfside Beach at the entrance to Anaheim Bay. He said he had been informed there are proposals for detached breakwaters to slow the rate of erosion adjacent to the south jetty. There is a mach stem reflection from the jetty that people have used for surfing since 1960, and they would like to retain that recreational resource. They would like to see an investigation of submerged structures that would slow the erosion rate, but at the same time retain the surfing resource. That project is moving ahead rather quickly, and they would like to work together and come up with some innovative solutions.

BOARD RECOMMENDATIONS

Prof. Dalrymple said his first comment was in regard to action item 51-4 concerning the use of other nations' labs, data, and expertise. Part of CERC's response was that they exchange publications, but that is not an up-to-date way to transfer information because publications lag the state of the art by a year or two. He thinks there need to be ways whereby there are personal exchanges and personal contacts between major international labs. In part, that means that foreign coastal engineers and scientists have to be able to come to CERC without undue restrictions. Present procedures inhibit visits by foreign nationals, in fact, isolating CERC and inhibiting informational exchanges. Conversely, CERC researchers need to be able to visit foreign labs, and that requires travel funding.

As an example, the International Conference on Coastal Engineering, which is held biannually, originated in the United States and is sponsored by the American Society of Civil Engineers. It works against the national interest when the number of CERC researchers participating in these conferences is very severely limited. These are meetings where state of the art is discussed, and other foreign labs send large numbers of participants. Limiting CERC participation inhibits technology transfer from other countries to the United States. Opening access to foreign visitors and permitting foreign travel for CERC researchers would redress some of the problems restricting technology transfer to CERC.

Prof. Dalrymple said other things that might be explored include more joint research with international labs, because as problems become more sophisticated and more expensive to research, it may be that some experiments cannot be carried out by one institution, and we should pool resources. He suggested personnel exchanges whereby people can spend time at CERC, and CERC investigators can spend time at other labs, looking at what is going on in those labs.

There are possibilities for computer connections between labs. Most United States universities are on INTERNET or BITNET, and some researchers in other nations are tied into BITNET. That might be a way to facilitate information exchanges.

Prof. Dalrymple said his other comment was on the Oceanside Sand Bypass plan. The next CERB meeting will have tidal inlets as a theme. He suggested that Oceanside should be a particular agenda item because it is using new technology and it would be worthwhile to see how effective it is.

Prof. Reid brought up the subject of quality control in the area of coastal research. He noted that a primary mechanism of quality control is publication in refereed journals. He recommended an incentive system within CERC to encourage investigators to publish in refereed journals.

Prof. Reid said that R&D for adequate design of breakwaters is a much neglected area. It has had low priority, particularly in the design of armor units. The amount of effort put into it has certainly not been commensurate with the costs of construction and maintenance of breakwaters. He recommended that cost-reimbursable studies should include an effort to make further measurements that would continue to upgrade our information in this particular area.

Prof. Raichlen said that what is really missing in the literature is the question of project failures. He thinks we can learn a great deal from our failures. In coastal engineering, he thinks this is especially true because we still do not understand a lot of the mechanisms behind fluid-structure interactions and the problems associated with sediment transport. He would like to see a program where the Corps gives attention to catastrophic events. The presentation on Hurricane Hugo indicated how we can mobilize people and get information before the information disappears. He would like to see, within Corps coastal Districts, teams set up that can respond very quickly to disasters, and also have the ability for members of CERC to go to the site to direct the teams so they can properly evaluate information which would be erased very quickly, in order to define some of the failures that do occur.

Prof. Raichlen said that working within a laboratory, a researcher can become very parochial. He thinks there is a great benefit to the researcher to take a sabbatical somewhere else for a period of time. He suggested that CERC look at this possibility, for researchers to spend 6 months out at a university laboratory, and possibly sit in on some courses to broaden their views in their areas of interest. In some respects, people would take their work with them, but it would get them out of the day-to-day problems and get them exposed to new ideas and insights.

Prof. Raichlen pointed out that university graduate programs have some very good foreign students that come through the programs. They have an 18-month period, after they finish their degrees, when they can do job training. While it is difficult for foreign visitors to come to CERC, it is something which one should think about in terms of long-range considerations. While such students would benefit from working at CERC, they would also transfer technology into CERC because they have been performing state-of-the-art research at the universities.

COL Wilson said that, recognizing the economic importance of the surfing industry and its environmental influence, it is recommended that the CERB write to the west coast Commanders, including the Pacific Ocean Division, encouraging them to factor the surfing interests into their planning, engineering, and operation and maintenance activities, so that the Corps might take advantage of that area of interest; and also make Corps projects, that lend themselves to it, more in-line with some of the recreational and environmental interests, as well as the economic interests.

CLOSING REMARKS

COL Wilson said that, on behalf of General Kelly and the other members of the Board, he would like to thank all the presenters for the very excellent briefings. He thanked Mrs. Sharon Hanks for her efforts in putting the meeting together. He expressed his appreciation to Art Shak and the other personnel from the District and Division for their efforts, and he thanked the people who put together the field trip, particularly Ted Baldau. He announced that the next meeting would be in Fort Lauderdale, Florida, in the spring of 1990, and the theme would be Coastal Inlets. The fall 1990 meeting will be in New Orleans, and the theme will be Coastal Flood Protection.

APPENDIX A

BIOGRAPHIES OF SPEAKERS/AUTHORS

ALAN E. ALCORN

Mr. Alcorn has been with the Los Angeles District since 1980. He is presently Assistant Chief of the Planning Division. Previously, he was the Chief of the North Coast for Coastal Resources Branch. His duties included oversight for several feasibility studies such as Redondo Beach Harbor, Los Angeles/Long Beach Harbors, and other harbors of Morro Bay, Ventura, and Santa Barbara. Mr. Alcorn was put in charge of the task force assigned to repair damage along the California coast sustained by the 1982-83 storms. He received his B.S. degree in civil engineering from San Diego State University in 1985 and attended courses in Delft, The Netherlands, in 1986 in port and coastal engineering, receiving the equivalence to a master's degree. Mr. Alcorn is a registered civil engineer in the State of California.

LOUIS B. ALEXANDER

Mr. Alexander is the Director of Land Use and Public Facilities Planning for the San Diego Association of Governments (SANDAG). He has been with SANDAG since 1973, directly involved in comprehensive planning for regional environmental issues and in the resolution of conflicts between public facility development and environmental concerns. Prior to locating in San Diego, Mr. Alexander worked for 5 years for the City of Indianapolis. He was educated at Ball State and San Diego State Universities.

HONORABLE LARRY M. BAGLEY

Mayor Bagley has been Mayor of Oceanside for 9 years. He is a native of Salt Lake City, Utah, and came to Oceanside in 1959, to take a position in the City Planning Department. Mayor Bagley has held various positions in the City of Oceanside, including City Manager (1970-75) and Planning Director (1962-70), and has served as a private consultant (1975-80). He received his degree from the University of Utah in political science/public administration. Mayor Bagley was featured in the San Diego Magazine as one of the people to watch in 1986. He was in Who's Who in Government (1975-76) and Who's Who in the West (1974-75). He is a member of the Rotary Club, Elks Club, US Conference of Mayors, and SANDAG and has served on the State Energy Committee. Mayor Bagley, a leader in beach restoration, is chair and founder of SANDAG's Beach Erosion Committee. He has spearheaded efforts to complete Oceanside's $21.5 million sand bypass project. He also guided acquisition and creation of Ivey Ranch Park. His leadership in opposition to Federal offshore oil development in the area has helped place Oceanside in the forefront of communities

opposed to offshore oil drilling. He also strongly advocates redevelopment of the city's downtown and beach areas.

STANLEY J. BOC, JR.

Mr. Boc earned a B.A. degree in earth science from Bridgewater State College in Massachusetts in 1972 and an M.S. degree in marine science (coastal engineering) from North Carolina State University in 1977. After graduation, Mr. Boc became a lecturer in geology and geography at the University of North Carolina at Wilmington for 2 years. The next year was spent as a regional specialist in coastal engineering for the New York State Sea Grant Program. Mr. Boc began his civil service career as a hydraulic engineer, coastal engineering specialist, for the Chicago District in 1980. From 1982 to present, Mr. Boc has served as a hydraulic engineer, coastal engineering specialist, for the Pacific Ocean Division (POD). He has extensive experience in the planning and design of coastal projects, primarily in the area of navigation and shoreline erosion control throughout POD's jurisdiction, which includes Hawaii, Guam, American Samoa, and the Commonwealth of the Northern Marianas, as well as the countries of Western Samoa, the Republic of the Marshall Islands, and the Federated States of Micronesia.

MG ROBERT M. BUNKER

MG Bunker became Commanding General and Division Engineer of the South Atlantic Division in July 1988. Prior to his current assignment, he was the Director of Management, Office of the Army Chief of Staff, in Washington, DC. MG Bunker's previous experience within the Corps of Engineers includes service as Deputy District Engineer in Mobile, Alabama; District Engineer Far East in Seoul, Korea; and Commanding General of the Pacific Ocean Division in Honolulu, Hawaii. He has also served as Assistant Commandant of the Army Engineer School, Commander of the 307th Engineer Battalion (82d Airborne Division), and Commander of the Army's Floating Nuclear Power Plant *Sturgis* and has had two earlier assignments within the Army Chief of Staff's Office.

A 1958 graduate of the United States Military Academy, MG Bunker also holds master's degrees in civil and nuclear engineering from the Massachusetts Institute of Technology. He is a graduate of the Army's Command and General Staff College and a Distinguished Graduate of the National War College. He is a registered professional engineer in Virginia; a member of Tau Beta Pi, the National Engineering Honor Society;

opposed to offshore oil drilling. He also strongly advocates redevelopment of the city's downtown and beach areas.

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a Regional Vice President of the Society of American Military Engineers; and the author of several technical papers and articles.

H. LEE BUTLER

Mr. Butler serves as Chief, Research Division, Coastal Engineering Research Center (CERC), US Army Engineer Waterways Experiment Station (WES). He directs a broad range of laboratory and field research studies/projects on forces and processes involved in beach erosion, hurricane action, sedimentation, and tidal hydraulics. He joined WES in 1973 as a team leader in the Wave Dynamics Division of the Hydraulics Laboratory directory numerical and analytical studies, and when CERC moved to Vicksburg in 1983, Mr. Butler was selected to serve as Chief, Coastal Processes Branch. Prior to joining the Corps of Engineers, he was a senior scientist with the National Engineering Science Company and Tetra Tech, Inc., during the years 1964 through 1973. Both firms were located in Pasadena, California. His responsibility involved the development and application of numerical models in many subfields of civil engineering with emphasis in the field of hydrodynamics. Mr. Butler received a B.A. degree in physics and mathematics from the University of St. Thomas at Houston, Texas, and an M.S.A. degree in mathematics from the University of North Carolina at Chapel Hill, North Carolina. Mr. Butler is a member of the American Society of Civil Engineers (ASCE), International Association for Hydraulic Research, Society of American Military Engineers, and the American Geophysical Union. He is also a member of the Corps of Engineers Committee on Tidal Hydraulics. He received the WES Commander and Director and the US Army Research and Development Achievement Awards (1984) and has published numerous technical articles and reports.

ROBERT W. CAUGHLAN

Mr. Caughlan has been surfing regularly for nearly 30 years. He has won numerous northern California trophies and surfed his way into three California championships. Mr. Caughlan earned a B.A. degree in political science and international relations from San Francisco State College in 1967. He worked for a political campaign management firm, Weiner and Company, whose campaigns included US Senator Alan Cranston, Congressman Pete McCloskey, for the San Francisco Supervisor, Mayor Dianne Feinstein, Superintendent of Public Instruction Wilson Riles, and Senator Jay Rockefeller. He served for 4 years as Field Representative to the late Congressman Leo Ryan. In 1973, Mr. Caughlan co-founded The Roanoke Company, a

media communications firm that specializes in social issues marketing. Roanoke's current projects include the California State Department of Fish and Game's Endangered Species Program and the California Highway Patrol's Motorcycle Safety Program. From 1976-80, Mr. Caughlan served as Special Assistant to the Administrator of the US Environmental Protection Agency (EPA) and in the White House on solar energy policy and international environmental issues. He is also currently the general partner in an 11-hour television series about international environmental issues featuring William Shatner and Faye Dunaway which will premier in the spring of 1990. Mr. Caughlan teaches a course on public service advertising at the Academy of Art College and has written numerous magazine articles on surfing and environmental politics.

C. E. CHATHAM, JR.

Mr. Chatham has been Chief of the Wave Dynamics Division since CERC's move to WES in 1983. He is responsible for experimental research in coastal engineering using CERC's two- and three-dimensional laboratory facilities. Mr. Chatham has been employed at WES since 1963 and previous assignments include Chief, Harbor Wave Action Branch; Chief, Wave Processes Branch; and acting Chief, Wave Dynamics Division, all in the Hydraulics Laboratory. He has a B.S. degree in civil engineering from Mississippi State University and graduate courses in hydraulic and coastal engineering at the WES graduate center. He is a registered professional engineer in the State of Mississippi and a member of ASCE and Permanent International Association of Navigation Congresses.

GEORGE W. DOMURAT

Mr. Domurat is a coastal engineer in the Coastal Engineering and Water Management Branch of the US Army Engineer Division, South Pacific (SPD). He received a B.S. degree in oceanography from Stockton State College in 1974 and an M.S. degree in physical oceanography from Old Dominion University in 1977. Mr. Domurat started with the US Army Engineer District, San Francisco, in 1977 and has been involved in harbor and channel design, shoreline erosion and protection studies, development of coastal field data collection programs, and data collection at the San Francisco Bay-Delta Tidal Hydraulic Model. He was with the SPD Planning Division from 1984 to 1987 and acted as the Chief, Coastal Engineering Section, Los Angeles District, during 1987-88. He is a Vice-President of the American Shore and

Beach Preservation Association and President of their chapter. He is also a member of the Marine Technology Society and the Coastal Society.

COL LARRY B. FULTON

COL Fulton became the 25th Commander and Director of WES in August 1989. Prior to his assignment at WES, he served as the Assistant Chief of Staff Engineer for the Southern European Task Force in Vicenza, Italy COL Fulton has a B.S. degree in civil engineering from the University of Colorado and an M.S. degree in civil engineering from Oklahoma State University. He is also a graduate of the Industrial College of the Armed Forces. Other command assignments include Company Commander, 70th and 84th Engineer Battalions, Vietnam; Commander 4th Engineer Battalion, 4th Infantry Division (Mechanized), Fort Carson, Colorado; and Commander and District Engineer of the Far East District, Korea. His major staff assignments include Egypt Area Engineer, Middle East Division; Assistant Director of the Directorate of Engineering and Construction, Headquarters, Washington, DC; Deputy District Engineer, Omaha District; Instructor, Department of Tactics, Fort Leavenworth, Kansas; Resident Engineer, US Army Engineer Command Europe, Augsburg, Germany; Executive Officer, 20th Engineer Battalion, Vietnam; and Platoon Leader and Operations Officer, 23rd Engineer Battalion, Germany.

DR. JAMES R. HOUSTON

Dr. Houston is Chief of CERC, WES. He has worked at WES since 1970 on numerous coastal engineering studies dealing with explosion waves, harbor resonance, tsunamis, sediment transport, wave propagation, and numerical hydrodynamics. He is a recipient of the Department of the Army Research and Development Achievement Award. Dr. Houston received a B.S. degree in physics from the University of California at Berkeley, an M.S. degree in physics from the University of Chicago, an M.S. degree in coastal and oceanographic engineering, and a Ph.D. in engineering mechanics from the University of Florida.

GARY L. HOWELL

Mr. Howell is a research engineer in the Prototype Measurement and Analysis Branch, CERC, WES, a position held since November 1983. He received B.S. and M.S. degrees in electrical engineering from the University of Florida. He has held engineering positions in industry with IBM Corporation and Honeywell-Bull, France. He

served as assistant director of the Coastal Engineering Laboratory at the University of Florida until 1983. While there, Mr. Howell developed the Florida Coastal Data Network field wave and storm surge measure system. He has served as a consultant in the areas of coastal and ocean instrumentation and maintains current research interests in the development of advanced instrumentation and data analysis techniques for coastal and ocean engineering. Mr. Howell is a member of the Institute of Electrical and Electronic Engineers and Eta Kappa Nu, and he is a registered professional engineer in the State of Florida.

WILLIAM H. IVERS

Mr. Ivers was appointed Director of the California Department of Boating and Waterways by Governor George Deukmejian on 11 May 1983. Prior to his appointment, Mr. Ivers served two terms (1978-82) in the State Assembly. He is a graduate of Loyola University, Los Angeles, with a B.A. degree in economics and served in the US Air Force from 1952 through 1956. He is the president of the National States Organization for Boating Assess, a past member of the National Boating Safety Advisory Council, and a member of the Board of Directors of the Tournament of Roses.

DR. A. L. KADIB

Dr. Kadib earned his Ph.D. degree in civil engineering from the University of California in Berkeley in 1965. He is presently Chief of the North Coast Section in the Planning Division of the Los Angeles District. Dr. Kadib has 30 years experience in coastal engineering in the private sector. He is also a part-time professor in coastal engineering and hydraulics at California State University in Long Beach. Dr. Kadib has over 70 publications in the field of coastal engineering and sediment transport.

DR. GERALDINE KNATZ

Dr. Knatz earned a B.A. degree in zoology from Rutgers University in 1973, an M.S. degree in environmental engineering in 1977, and a Ph.D. degree in biological sciences in 1979 from the University of Southern California. She has had 12-years experience in port planning environmental management. Dr. Knatz is currently Director of Planning for the Port of Long Beach and is responsible for Master Planning, Transportation Planning, Environmental Planning, and Market Research sections. She is Project Manager for the Port of Long Beach 2020 Plan and Consolidated Rail Corridor Projects. Dr. Knatz is a member of the American Association of Port

Authorities Planning Committee. She was formerly employed as an environmental scientist by the Port of Los Angeles. Dr. Knatz is also currently Adjunct Professor of Civil Engineering at the University of Southern California; Adjunct Professor of Public Policy at California State University, Long Beach; instructor in geography at the University of California at Los Angeles; and instructor in family history at Los Angeles Harbor College.

DAN T. KOCHI

Mr. Kochi has held the position of Deputy Director, Department of Transportation, State of Hawaii, since 1987. He is responsible for the management of the Harbors Division and operations of ports in the state. Prior to becoming Deputy Director, Department of Transportation, Mr. Kochi was Deputy Attorney General, Department of Attorney General, State of Hawaii, from 1983-86, in which position he was assigned as counsel to the Hawaii Housing Authority. From 1979-83, Mr. Kochi was an associate with Carlsmith, Carlsmith, Wichmann and Case. Mr. Kochi received his B.S. and M.S. degrees in electrical engineering from the University of California, Berkeley, in 1970 and 1973, respectively. In 1973, he received is J.D. degree from Hasting College of the Law.

DR. NICHOLAS C. KRAUS

Dr. Kraus is a senior scientist in the Research Division, CERC, WES, working in the area of coastal sediment transport processes. He jointed CERC in 1984 and previously was a senior engineer at the Nearshore Environment Research Center, Tokyo, Japan. Dr. Kraus is the Technical Manager of the Dredging Research Program area "Analysis of Dredged Materials Disposed in Open Waters," where he heads a group of five principal investigators involved with the mathematical prediction and field measurement of the movement of dredged material. In the Coastal Research Program, Dr. Kraus was co-developer of the shoreline change numerical simulation GENESIS and the storm-induced erosion model SBEACH. He is a member of ASCE, currently serving as Chairman of the ASCE specialty technical conference Coastal Sediments '91, American Geophysical Union, and Society of Economic Paleontologists and Mineralogists. In 1987, Dr. Kraus received the US Army Research and Development Achievement Award.

DWAYNE G. LEE

Mr. Lee is Deputy Executive Director of Development for the Port of Los Angeles. He joined the Port of Los Angeles in June 1989 after retiring with the rank of Colonel from the US Army. While in the military, Mr. Lee was the 24th Commander and Director of WES from July 1986 until his retirement and prior to that time was Commander of the Louisville District. His major command assignments include Commander, 27th Engineer Battalion, Fort Bragg, North Carolina, and Company Commander, 168th Engineer Battalion, Vietnam. His major staff assignments include Team Chief, Military Engineering Division, Office of the Assistant Chief of Engineers, Washington, DC; Operations Officer, Headquarters, 18th Airborne Corps, Fort Bragg, North Carolina; Area Engineer, Japan Engineer District, Okinawa; Staff and Faculty Member, US Military Academy, West Point, New York; and Operations Officer, 809th Engineer Battalion, Thailand. He is a 1964 graduate of the US Military Academy at West Point. He received a master's degree from the US Air Force Institute of Technology in Dayton, Ohio, and is a graduate of the Army Command and General Staff College and the Industrial College of the Armed Forces. He is a registered professional engineer in the State of Virginia.

DAVID D. McGEHEE

Mr. McGehee is currently employed by CERC, WES, as a hydraulic engineer conducting research in nearshore processes, wave/structure interaction, and tidal hydraulics. As principal investigator of the Field Wave Gaging Program, he manages a national, real-time gage network used to develop a US coastal wave climate. Mr. McGehee received his B.S. degree in ocean engineering from Florida Atlantic University in 1973 and obtained professional registration in 1983. Previous experience includes the University of Florida's Coastal and Oceanographic Engineering Laboratory and the dredging, marine construction, and offshore service industries.

JEFFREY A. MELBY

Mr. Melby is a research hydraulic engineer in the Prototype Measurement and Analysis Branch, Engineering Development Division, CERC, WES. Mr. Melby joined CERC in 1987 after receiving an M.S. degree in ocean engineering at Oregon State University. Mr. Melby's work has concentrated on developing a concrete armor unit structural design procedure. As a graduate student, Mr. Melby developed and applied a wave force numerical model for dolosse. He has published several papers on the

static and dynamic response of dolosse and is currently developing the Crescent City dolos structural design procedure. As the principal investigator in the Corps' Concrete Armor Unit Design work unit, Mr. Melby is extending the Crescent City design procedure to the general case, using a parametric physical study where the dolos structural response is measured by means of small-scale internal structural instrumentation.

DR. DONALD K. STAUBLE

Dr. Stauble is a team leader of the Coastal Geology Unit of the Coastal Structures and Evaluations Branch of the Engineering Development Division, CERC. The Coastal Geology Unit investigates geologic process and response changes to the coastlines of the United States. These studies encompass a broad range of research topics, including historic shoreline trends, beach nourishment technology, barrier island and other coastal sedimentation processes, coastal engineering geographic information system, and remote sensing image analysis, the effect of sea level rise, and general research into coastal geomorphic and geologic problems pertinent to the Corps of Engineers. Dr. Stauble earned his B.S. degree in geology from Temple University in 1969, his M.S. degree in oceanography from Florida State University in 1971, and his Ph.D. degree in marine/environmental science from the University of Virginia in 1979. Prior to working at CERC, he taught and conducted research for 9 years in the Department of Oceanography and Ocean Engineering at the Florida Institute of Technology. His research has been in the fields of beach nourishment technology; coastal processes; storm-induced beach changes; inlet, beach, shoal, and estuarine sediment transport and morphology; and coastal remote sensing. Dr. Stauble is a member of the Society of Economic Paleontologist and Mineralogist, American Shore and Beach Preservation Association, Florida Shore and Beach Preservation Association, American Society of Photogrammetry and Remote Sensing, American Geophysical Union, and the Marine Resources Council of East Central Florida.

JOHN F. WARWAR

Mr. Warwar is a civil/structural engineer with 30 years of worldwide experience, encompassing planning, design, and construction management of ports and harbor projects, as well as transportation and public works programs. He has in-depth knowledge of the maritime industry and has been a long-time active participant and contributor to such organizations as AAPA, ASCE, and PIANC. Mr. Warwar has authored a number of technical papers relating to port and harbor planning and

design. He has held numerous managerial positions during his career, and he is presently the 2020 Program Director for the Port of Los Angeles.

LTC DONALD T. WYNN

LTC Wynn became the Commander and District Engineer of the US Army Engineer District, Honolulu, in July 1989. Prior to this assignment, LTC Wynn was the Deputy Commander-Military for the Seattle District and served a tour as the Deputy Chief of Staff, Engineers, in Honduras. Other command and staff assignments include project office, Directorate of Combat Developments at the Engineer School, Fort Lewis, Washington; executive officer, 11th Engineer Battalion at Fort Belvoir, Virginia; deputy area engineer at Taif Area Office, Saudi Arabia; and associate professor of physics at the US Military Academy, West Point.

A 1971 West Point graduate, LTC Wynn is a registered professional engineer in the State of Virginia. He earned his M.S. degree in applied science from the University of California at Davis in 1977 and his M.B.A. degree from Long Island University in 1980.

APPENDIX B

STATUS OF ACTION ITEMS

[illegible] ITEM	PLACE AND DATE OF ACTION	RESPONSIBLE AGENT	ACTION AND STATUS
1-1. President of CERB should have a dialogue with the Commander of Engineer [illegible] relating to training of [illegible] in coastal specialty [illegible] AEPB requirement).	Wilmington May 89	CECW-P	Action deferred pending establishment of [illegible] Engineering [illegible] Program.
1-2. Report on procedures [illegible] transferring complex numerical models from the [illegible] the field (e.g. [illegible]).	Wilmington May 89	CERC	Complete. Numerical models will be trans- ferred through a [illegible] Modeling System.
1-3. Report on process used [illegible] numerical and physical modeling.	Wilmington May 89	CERC	Complete. Physical models routinely used for data to evaluate and develop numerical models.
1-4. Establish a mechanism [illegible] visibility/use of [illegible] data/ [illegible], e.g., German [illegible].	Wilmington May 89	CERD CERC	Various means used [illegible] personal contacts [illegible] formalized information exchanges. Problem with limits on foreign travel. See Items 52-1 and 52-2. Technical Director of WES handling PIANC breakwater working group.
1-5. Publish John Housley's results from the follow-up [illegible] low-cost shore protection.	Wilmington May 89	CECW-P	Funding available in FY90. Action proceeding.
1-6. Ensure that present coastal engineering R&D is flexible, to work beyond present policy snapshots.	Wilmington May 89	CERC	Complete. Field Review Group and Technical Monitors support research with benefits in intermediate to long term.
[illegible]1-7. Determine whether NOAA or Minerals Management Service is mapping coastal sand resources. If not, should Corps establish a program to map the resources.	Wilmington May 89	CERC CERD	US Geological Survey performing offshore surveys. CERC will complete contacts and report findings.
[illegible]1-9. Review establishment of [illegible].	Wilmington May 89	CERC	Complete. Universities have been contacted. CERC has joined one university consortium submitting a proposal.

51-9. Include a discussion on determining coastal project benefits at the Florida meeting in May 1990.	Wilmington May 89	CERC	Discussion will be included at Ft. Lauderdale meeting. Planning and IWR will be contacted.
51-10. Get coastal engineering added to SKAP categories other than R&D.	Wilmington May 89	CECW-P	Personnel Office, HQUSACE, has been opposed. Issue will be revisited and discussed with Career Planning Board.
50-5. Review and modify as required current design guidance on small storm surgers. Report progress at next CERB.	Virginia Beach Nov 88	CEEC	Complete. Areas requiring development have been identified. New guidance will be issued as it becomes available.
50-12. Explore potential for sharing with coastal states, Corps execution of its coastal R&D responsibilities.	Virginia Beach Nov 88	CERD	A draft cooperative agreement with the State of California for data collection has been forwarded to HQUSACE for approval. Model for other state agreements. Presently undergoing review in the Office of Counsel.
50-17. CERB should consider land use issues. Example, should Corps provide protection to condominium at mouth of Chesapeake Bay. What are policies?	Virginia Beach Nov 88	CECW-P	Complete. Land use controls are a local government issue. Corps approaches problem through the NED test and NEPA criteria.
49-5. Explore possibilities and merits of establishing a Great Lakes Technical Information Center as a repository for Great Lakes coastal information.	Oconomowoc May 88	CENCE	Complete. Computerized Geographic Information System being developed by Great Lakes States and Corps under International Joint Commission sponsorship.

APPENDIX C
COAST OF CALIFORNIA STORM AND TIDAL WAVE STUDY
PLANNER'S HANDBOOK
SUBMITTED BY
LOUIS B. ALEXANDER

COAST OF CALIFORNIA STORM AND TIDAL WAVE STUDY
PLANNER'S HANDBOOK

Louis B. Alexander
San Diego Association of Governments
San Diego, California

Purpose:

To inform the Coastal Engineering Research Board (CERB) of how local interest has been involved in the development of the Coast of California Storm and Tidal Wave Study (CCSTWS) in the San Diego region, the value of local participation to the study, how the results of the study are expected to be used locally, and the potential for expansion of the study to other parts of the State of California. The Planner's Handbook is the focus for translating the CCSTWS information into tools for managing the shoreline in the San Diego region.

Background:

a. Evolution of shoreline protection as a priority issue in the San Diego region--establishment of the Shoreline Erosion Committee (SEC) by the San Diego Association of Governments (SANDAG) Board. (Storm damage in 1977 and 1978 focused public sentiment.)

b. Local role in the start-up of the CCSTWS and its initial focus on the San Diego region coastline. (SANDAG role in initiating authorization of funds for CCSTWS.)

c. Role of the SANDAG Shoreline Erosion Committee as local liaison for the CCSTWS over the past 9 years--staff function for SANDAG as well.

Functions of SEC:

a. Review work programs, provide local perspective on shoreline problems and information needed to solve them.

b. Keep the public informed on progress of the study.

   (1) Quarterly Bulletin--statewide.

   (2) Conferences--statewide.

   (3) Presentations to SANDAG Board, local governments.

c. Advocacy for continuing Federal support.

CCSTWS Planner's Handbook: Focus for Local Participation

a. Handbook objectives are to make the CCSTWS available to local planners and decision makers in a format they can understand and use in a coordinated manner to manage the shoreline. It is considered one of the most important products of the CCSTWS.

b. The Corps gave SANDAG, as agency coordinating local liaison, a key role in developing the Handbook.

(1) Writing the parts of the Handbook relating to the implementation of shoreline management strategies, projects using the technical information from the CCSTWS.

(2) Editing the production of the entire Handbook for maximum readability, understandable graphics, and overall appeal.

(3) Coordinating local review and input in development of the Handbook.

c. Process used to ensure full public input and involvement in the Handbook. The Corps and SANDAG believe that if local planners and decision makers are to use the Handbook, they must be closely involved in its development. The process included:

(1) Using the SANDAG Shoreline Erosion Committee to review and comment on the initial outline and work plan for developing the Handbook.

(2) Three one-half day workshops with local government staffs, elected officials, and interested citizens in the region's three littoral cells.

(3) In-depth interviews with key staff people in each of the cities in the region with shoreline, as well as with State (parks) and Federal (DOD) agencies with shoreline--to determine existing policies and procedures relating to shoreline management.

(4) Review process for the draft Handbook including SEC review and additional local workshops.

Next Steps: Using the Handbook as the Basis for a Shoreline Action Plan in the San Diego Region

a. Local involvement in the CCSTWS has aided the development of an informed and active constituency for the shoreline in the region. As the CCSTWS, and particularly work on the Planner's Handbook, has proceeded, the SEC has developed the concept of a "Shoreline Preservation Strategy" which would take the CCSTWS and Planner's Handbook the next step--to create an Action Plan for managing the region's shoreline resources.

b. Discussion of highlights of strategy--see attached Work Plan.

Conclusion

CCSTWS is an example of the importance of local participation and support of science and engineer programs like the CCSTWS. Preceding remarks have illustrated the mutual benefits--to the study and the local area--of this relationship:

a. Study is informed of local needs, perceptions, and data that can be very useful in design and carrying out the work.

b. Study receives local support that can translate into stronger long-term funding commitments.

c. More informed local constituency is developed, increasing certainty that the study results will be used.

San Diego region experience in working with the Corps on the CCSTWS has been positive and mutually beneficial for the past 8 years. We look forward to a very cooperative and exciting future in turning the CCSTWS into an effective shoreline action plan.

SANDAG SHORELINE PRESERVATION STRATEGY
SCOPE OF WORK

Task:

1. Translate technical data from Coast of California Study and other sources into problems and possible solutions for specific shoreline areas and define relationships and interactions among problems areas, coastal processes, and solutions.
   a. Identify problem areas along shoreline (by littoral cell segments).
   b. Identify key coastal processes at work in each littoral cell and each problem area segment of the littoral cells.
   c. Identify types of solutions, both structural and management, available for each problem coastal segment, along with rough cost estimates, and implementation responsibilities.
   d. Evaluate and compare potential solutions for each problem's coastal segment, including effectiveness, cost, impacts on other shoreline segments, and impacts on the environment. ("First cut analysis" would be refined when specific projects are planned and designed.)
   e. Identify a cost-effective regionwide program of wave and shoreline monitoring to support future project-specific engineering and design studies.
2. Develop financial strategies to find solutions to shoreline erosion problems.
   a. Identify existing potential sources of funding, primarily State and Federal.
   b. Identify innovative local sources of funding, such as assessment district, transient occupancy taxes, user fees, and ways to get support from special local participants such as the Port District and the US Navy.
   c. Evaluate and compare alternative financing methods according to criteria such as fund availability, ease of implementation, equity, and long-term continuity. Evaluate groups of compatible funding methods for ability to meet costs identified in Task 1.
3. Develop institutional strategies for implementing solutions to shoreline erosion problems.
   a. Identify existing Federal, State, and local organization with a role in shoreline preservation or an impact on shoreline erosion.
   b. Identify innovative Federal/State/local institutional structures such as joint powers agencies which could assist in carrying out the shoreline preservation policy.
   c. Evaluate and compare alternative institutional structures according to criteria such as potential effectiveness in implementing solutions, ability to secure funding, set-up cost, and administrative expense, and ability to coordinate public and private decision making.
4. Public education and participation.
   a. Develop materials to communicate the key information from Tasks 1, 2, and 3 to local elected officials, Federal, State, and local agency managers, and the public, including media such as newsletters, brochures, and slide shows.
   b. Develop and carry out programs to present the materials in subtask (a), above, in a structured way with the objectives of encouraging participation and developing a consensus on technical issues and financial and institutional strategies.
5. Policy development.
   a. Based upon results of comments and recommendations received in the public participation program, develop a draft Policy and Program to preserve the region's

shoreline, including management solutions, financing and institutional strategies, and a budget and schedule of implementation activities.

b. Develop a process for obtaining a formal commitment to the Policy and Program from responsible local governments and State and Federal agencies.

6. Adoption and implementation of Shoreline Preservation Policy and Program.

a. Carry out subtask 5b.

b. Implement, monitor, revise, and update Shoreline Preservation Strategy.

APPENDIX D
PUBLIC COMMENTS

TEKMARINE

May 22, 1990

Coastal Engineering Research Center
Waterways Experiment Station
Department of the Army
Corps of Engineers
3909 Hales Ferry Road
Vicksburg, Mississippi 39180-6199

Attention: James R. Houston, Ph.D.
Chief, CERC

Dear Jim:

Jim, I would like to express interest in being considered for membership on the Coastal Engineering Research Board when a vacancy comes up in the future. Membership on this board is a great personal prestige, and I sure feel awkward in making an open bid for it; but, I have been motivated to do so by a strong feeling that as board member I can be an effective campaigner for the growth of CERC.

The individual asset that will support me as a useful member on the board is a balanced experience as practicing coastal engineer (for about 18 years at both Tetra Tech, 1973-79, and Tekmarine, 1979-present) and as research engineer (for about 15 years since MS in 1958, through Ph.D. in 1961, both at Univ. of Tokyo; Assistant Professor at University of Florida 1963-65, and Associate Professor and Professor at LSU 1965-73). All through my career, I have endeavored to bring the best of science into engineering practices, and my track records show that I have at least tried hard to approach that goal. I may count as my credentials a rather serious flirtation with arctic coastal and offshore construction, ship motion dynamics, EIR/EIS, remote-sensing application to coastal and shallow-water processes, and major overseas experience, in addition to sediment and coastal morphodynamics with which I still carry on life-long love affair.

Thank you very much for the opportunity to convey my thought to you.

Sincerely,

Choule

Choule J. Sonu

Surfrider
Foundation

November 12, 1989

Colonel Larry B. Fulton, Executive Secretary
Coastal Engineering Research Board
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, Mississippi 39180-6199

Re: Public Comment / 19 Oct 89
52ND Meeting of the Coastal Engineering Research Board

Herein are written comments summarizing oral comments presented to the Coastal Engineering Research Board 19 Oct 89.

My name is Thomas Pratte, and I am the executive director of The Surfrider Foundation. Yesterday, Rob Caughlan addressed your board and presented a broad overview of the surfer's perspective. Today, I would like to make some specific recommendations for undertaking innovative measures that will protect and enhance recreational uses of the shoreline environment.

1. We encourage the placement of offshore sand bars in beach nourishment projects along open coastal waters exposed to wave action.

   Many beach replenishment projects extend the berm seaward creating over-steepened slopes and poor surfing conditions.

   Offshore bars are natural features along sandy beaches under equilibrium conditions. Where these occur, surfing conditions are often good.

   It is anticipated that the placement of offshore bars will help build beaches while maintaining or even enhancing wave conditions for recreation.

   In addition, this method of placement may have potential to extend the windows of time for dredging operations. Research on the placment of sand in offshore bars should be undertaken with respect to environmental constraints (e.g. grunion spawning and least tern nesting).

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2. We encourage the Corps to undertake research on wave transformation over 3-dimensional slopes. The Surfrider Foundation is interested in building reefs for enhanced ocean wave recreation. Other positive public benefits could include shoreline stabilization and marine habitat enhancement.

   If asked to conceptualize a submerged shore-parallel coastal structure, many coastal engineers would envision a breakwater with steep slopes (2:1 or 3:1) oriented parallel to shore. This type of a structure will generally be destructive to otherwise good surfing conditions.

   We are interested in evaluating structures of low relief with broad slopes oriented at an angle to shore. We'd like to analyze breaking wave characteristics with respect to the orientation, slopes and depths of submerged shoals. We'd like to investigate the effect of a shoal on a beach. And, we'd like to undertake large scale stability studies.

   These kinds of studies will present opportunities to advance our understanding of the behavior of breaking waves both theoretically and for application in coastal engineering design.

3. Currently, the Corps of Engineers is involved in the design of coastal structures that would have an effect on existing surfing resources in southern California. These include the Ventura Harbor Navigation Improvement project and the Surfside/Anaheim Bay Jetty project.

   We are interested in viewing the model for the Ventura Harbor to investigate the proposed groin at South Beach. In addition, we'd like to be involved in the design of any improvements at the Surfside/Anaheim Bay Jetty. At Surfside, there may be potential to design a submerged shoal to reduce the local rate of erosion.

<u>SUMMARY</u> We hope to have opportunities to work with the Corps' Coastal Research Program towards developing innovative solutions where the interests of surfriders can be accomodated in the design of coastal projects (including sand bypassing, beach replenishment and the design of coastal structures).

Thank you for this opportunity to speak.

Sincerely,

THE SURFRIDER FOUNDATION

Thomas P Pratte

Thomas P. Pratte
Executive Director